Lecture Notes in Networks and Systems 1753

Álvaro Rocha
Francisco J. García-Peñalvo
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Contents

Workshops

Accounting and Auditing Cryptocurrency: A Literature Review 3
Isabel Maldonado, Carlos Pinho, and Amélia Ferreira da Silva

Challenges of Artificial Intelligence in the Accounting Profession 16
Sara Pinho, Helena Costa Oliveira, Isabel Maldonado, and José de Campos Amorim

Evaluating the Impact of Smart Contracts on Public Transportation: A Systematic Literature Review 27
Soraya González-Mendes, Joao Tiago Aparicio, and Carlos J. Costa

Active Learning Strategies in the Context of Society 5.0 39
Elisabete Vieira and Mara Madaleno

Artificial Intelligence System for Digitization of Traditional Folk Music Performances 50
Álvaro Lozano Murciego, Diego M. Jiménez-Bravo, Daniel Hernández de la Iglesia, Héctor Sánchez San Blas, and Gabriel Villarrubia González

Agent-Based Model for Predicting the Impact of Generative AI 62
Joao Tiago Aparicio and Carlos J. Costa

Fight Food Waste and Promote Healthy Regional Cuisine Through a Mobile APP 73
Redney Manuel Monteiro, André Moreira, Elisabete Paulo Morais, and Carlos R. Cunha

Use of Extended Reality in the Tourism Sector: A Bibliometric Analysis Across Scopus and Web of Science Over the Last Ten Years 85
André Moreira, João Pedro Gomes, Vítor Mendonça, and Carlos R. Cunha

Digital Transformation in the Public Sector State of the Art in Local Government Bodies 99
Carlos Santos, Augusta Ferreira, and Helena Inácio

Hybrid Firefly-Grasshopper Optimisation Algorithm (FAGOA) for Optimizing Wireless Sensor Network Deployment 108
Eshtiag Jahalrasool Ahmed, Abdalla Akod Osman, and Sally D. Abualgasim

Work-in-Progress Traceability in Textile and Clothing Manufacturing: A Literature Review 112
Valdo Mpinga, A. M. Rosado da Cruz, Estrela F. Cruz, and Sérgio I. Lopes

Innovative Mosquito Breeding Site Detection: Leveraging YOLOv7 with Transformer Technology 123
Luis Augusto Silva Zendron, Álvaro L. Murciego, Diego Bravo Jimenez, Anita M. da Rocha Fernandes, Valderi R. Q. Leithardt, and Gabriel Villarrubia González

Cosmic Observatory, a Virtual Reality Game to Promote Computational Thinking 134
David Duarte, Cristiana Araújo, Pedro Rangel Henriques, Alexandre Cardoso, Maria Adriana V. Lima, and Angel Rodrigues Ferreira

The Process of Implementing International Accounting Standards: The Mozambican Public Administrative Sector 150
Maria C Tavares and Clemente Lourenço

Service Quality, Satisfaction and Loyalty Determinants in the e-banking 163
Anabela Maria Bello de Figueiredo Marcos and Tânia Vanessa Marques da Rocha

The Digital Presence of Universities: A Case Study on Green Taxation Courses 174
Sílvia Coutinho Santos, Ana Arromba Dinis, Liliana Pereira, and Shane O'Sullivan

Erasmus+ Projects and Science Communication in the Digital Era: The CARE Project Dissemination Plan 187
Margarida M. Pinheiro and Cláudia A. Santos

Science Communication Within Erasmus+ Projects: The FairFood Project 200
Margarida M. Pinheiro and Cláudia A. Santos

The Impact of Gender on Financial Decision-Making: A Case Study 212
Margarida M. Pinheiro and Adriana Ferreira

Accessibility of the Canvas and Blackboard Learning Management Systems: A Case Study at a Brazilian University 222
Daniella G. Portella, Luiz G. F. Sereno, Luiza B. Fernandes, Rafael A. Fujita, and Alessandra Alaniz Macedo

Emerging Technologies in the Public Sector: Impact on Anti-Corruption Strategies 235
Carlos Santos, Augusta Ferreira, and Helena Inácio

A Customizable Escape Game-Like Based on Computational Thinking Categorization 244
Maria Adriana Vidigal Lima, Renato Aquino Lopes, Rodrigo de Godoy Domingues, Felipe Canabarro Graffunder, Gabriel Henrique de Oliveira, Giovanna Lara Cabrera Gaspar, Guilherme Duarte Toffoli, Guilherme Henrique Andrade Otoni, Larissa Campos Cardoso, Luis Arthur Rabelo Barbosa, and Victor Hugo Borges

Development of an Augmented Reality Guide for a LASER Cutting Machine 258
Lucas Augusto Tavares de Moura, Márcio Sarroglia Pinho, and Filipi Damasceno Vianna

Financial, Tax and Accounting Literacy - a Study in the 12th year of Secondary Education 271
Liliana S. R. Nunes and Alberto J. Costa

Management Accounting in Portuguese Municipalities: Adoption and Disclosure 282
Alberto J. Costa, Ricardo Esteves, and Sónia Barbosa

Segment Reporting Systematic Review: An ADO-TCM Framework Approach 294
Rodrigo Matias, Diogo Vilela, Gonçalo Castro, Daniela Penela, and Ana Isabel Lopes

The Role of the Sustainable Development Goal 4 in Sustainable Education: A Literature Review 311
Maria C Tavares, Graça Azevedo, and José Vale

Accounting Information Systems in Quality Education 320
Maria C Tavares, José Vale, and Graça Azevedo

Roadmapping Cybersecurity for IoT-Enabled Smart Environments 332
Paulo Barros and Sérgio Ivan Lopes

Artificial Intelligence and Education-a New Matter 348
Rita Vieira, Patrícia Monteiro, Graça Azevedo, and Jonas Oliveira

Drivers of Brand Love and Brand Loyalty in a Technological Context the Sony PlayStation 358
Anabela Maria Bello de Figueiredo Marcos and Pedro Emanuel Balhau Nunes

Brand Engagement in Achieving Customer Satisfaction and Brand Loyalty for Sony's Gaming 373
Anabela Maria Bello de Figueiredo Marcos and Pedro Emanuel Balhau Nunes

Effect of Spending on R&D and STI Activities on Firms Productivity in Ecuador 388
Moreno-Hurtado Gabriela, Paladines-García Gabriela, Espinosa-Campoverde Doménica, and Moreno-Hurtado Carlos

Day Planner: An Accessible Serious Game to Support Social Communication in Children with ASD 401
Guilherme Rodrigues Santos, Talyta Scaramuzzo, Vitor de Sousa Uema, Cibelle Albuquerque de la Higuera Amato, and Maria Amelia Eliseo

Education 5.0: Opportunities and Challenges from Blended Learning 414
Ana Torres and Gabriela Beirão

Methodology for the Development of a University Microgrid Laboratory in Virtual Reality Applied to Engineering Education 423
Milena Freitas Teixeira, Daniel Rebouças Jaguaribe, Raimundo Furtado Sampaio, Giovanni Cordeiro Barroso, Antônio Jose Melo Leite Junior, Ruth Pastôra Saraiva Leão, José Marques Soares, Clemilson Costa dos Santos, Clarice da Costa Corrêa, and Alexandre Cardoso

Towards the Development of a Robust Continuous Auditing and Business Compliant System a Conceptual Proposal Using Blockchain and Machine Learning 437
João M. Carvalho, Gonçalo Carnaz, and Rui Pedro Marques

Enhancing Urban Regeneration Through Digital Transparency and Open Government 448
André Carvalho, Ana Dinis, and Liliana Pereira

Information Security in Universities Risk Management and Internal Audit 461
David Marques and Georgina Morais

Management Accounting and Digital Transformation in the Government Sector: A Science Mapping Review 469
Adriana Barreto, Patrícia Gomes, Patrícia Quesado, and Shane O'Sullivan

Leveraging Customer Audit: A Decision Support Dashboard 484
Diogo Morgado, Raul M. S. Laureano, and Maria Diniz

Patterns Beyond Words: Understanding Emotional Undertone on Knowledge Graphs 496
Joao Tiago Aparicio, Elisabete Arsenio, and Rui Henriques

Socio-Economic Consequences of Generative AI: A Review of Methodological Approaches 509
Carlos J. Costa, Joao Tiago Aparicio, and Mnuela Aparicio

Revolutionizing Military Communications with a Conceptual Blockchain Model for Enhanced Security and Trust 522
Carlos Bernardino

Characterization of the Tobacco Tax 534
Paulo Dias and Beatriz Vidal Pereira

Author Index 547

Workshops

Accounting and Auditing Cryptocurrency: A Literature Review

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Abstract. Accounting for cryptocurrency transactions and auditing is complex due to valuation, regulatory, and transparency issues, especially in the lack of accounting and audit standards. This article reviews existing research on crypto asset usage in accounting and auditing, employing bibliometric analysis and WoS and Scopus databases. It was possible to examine 55 relevant studies published since 2017 (date of publication of the first article in the databases), encompassing 36 sources and 121 authors. The results suggest that accounting regulators struggle with establishing standards for cryptocurrencies due to their unsuitability for existing frameworks. Also, the impact of crypto assets on auditing is in its early stages, requiring further empirical investigation. This research highlights the need to explore how auditors can effectively assess risks associated with digital currency transactions.

Keywords: Cryptocurrencies · financial reporting · accounting and auditing

1 Introduction

Accounting and auditing cryptocurrency transactions present a multifaceted challenge due to the unique nature of these digital assets, one of the main difficulties is determining the appropriate valuation method. Unlike other assets, cryptocurrencies are highly volatile, with their values subject to rapid fluctuations over short periods. This volatility makes it difficult to determine a reliable and stable valuation for financial reporting purposes and increases the risk ([1, 2]).

One of the most important parts of this problem turns out to be the lack of specific accounting standards adapted to cryptocurrencies. While existing accounting frameworks, such as GAAP and IFRS, guide various financial instruments, they mostly gloss over the complexities of cryptocurrency, providing at best only a few guidelines or no guidelines at all ([1]). So, while regulatory bodies debate whether to issue standards to regulate the accounting of cryptocurrencies, accounting and auditing professionals struggle to select the best reporting model for cryptocurrencies.

Not many research articles in the field of accounting and auditing analyse the complex technical aspects of cryptocurrencies and the associated accounting challenges, and

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regulatory bodies are still in the debate phase about the appropriate accounting treatment for crypto-assets ([3]).

In addition, [4] points out that the inherent anonymity and decentralized nature of many cryptocurrencies pose challenges to financial reporting and auditing processes. Transactions involving cryptocurrencies may lack the transparency and documentation typically associated with traditional financial transactions, raising concerns about accuracy, reliability, and auditability. The question arises as to whether accountants and auditors can rely on the reliability of blockchain and cryptocurrency systems and whether they can authenticate the accuracy of the accounting data presented ([5]).

Accounting and auditing of cryptocurrency transactions present significant challenges related to valuation, regulatory compliance, and transparency. Resolving these challenges requires collaboration between standard setters, regulators, industry stakeholders, and accounting and auditing professionals to develop comprehensive guidance that reflects the unique characteristics of cryptocurrencies, while ensuring transparency and accountability in financial reporting.

This paper aims to explore and critically analyse the current research regarding the impact use of crypto assets in accounting and auditing, by a bibliometric analysis of articles focused on cryptocurrency in the accounting and auditing areas.

2 Theoretical Background

Although we can say that the use of cryptocurrencies is nothing new, the accounting treatment of cryptocurrency transactions still raises many doubts. [6] points out that International Accounting Standard (IAS) 8 – Accounting Policies, Changes in Accounting Estimates and Errors establish that in the absence of a Standard or Interpretation that applies to a specific situation or transaction, entities should use their judgment in developing and applying an accounting policy that results in information that is relevant and reliable, leaving open what the best approach might be. The market is already demanding accounting standards in this area and different regulatory bodies at the international level have shown concern about providing guidance, but there are still no clear accounting guidelines ([1]).

The Australian Accounting Standards Board (AASB) Research Center, in a joint effort with CPA Australia and the University of New South Wales, published a report in 2023 that provides an overview of the perspectives shared by some Australian stakeholders on crypto asset accounting and reporting. The report shows that the stakeholders presented their concerns regarding challenges posed by the development of the cryptocurrency market and its consequent impacts on financial reporting, encouraging standard bodies to review and develop accounting standards or guidelines that take into account the characteristics of the different types of crypto assets. However, according to [[7], p.25], "Although some stakeholders acknowledged that it might be premature for standard-setters to develop specific accounting standards that address crypto assets at the current stage, they are of the view that standard-setters should provide some form of guidance or education guidance for preparers and auditors to navigate the accounting treatments of crypto assets."

Regarding the United States Generally Accepted Accounting Principles (US GAAP), in 2003 the Financial Accounting Standards Board (FASB) proposed a discussion about

accounting standard updates regarding Accounting for and Disclosure of Crypto Assets. Following this consultation, the FASB released an accounting standards update (ASU) (ASU nº 2023–08) on the accounting and disclosure of crypto assets. Under this update, entities are required to measure specific crypto assets at fair value subsequently, with any changes in fair value documented in net income during each reporting period. In addition, entities are required to provide supplementary disclosures about ownership of designated crypto assets.

The International Accounting Standards Board (IASB) itself has been discussing issues related to digital assets since 2018 and in 2021 published a request for information (RFI) asking stakeholders about new financial reporting issues that could be prioritized in the IASB's work plan, which included standards related to cryptocurrencies and related transactions. The responses regarding a potential project on cryptocurrencies and related transactions were not homogeneous, ranging from high priority to low priority. As a result, the IASB decided that it was not a priority to add a project on cryptocurrencies and related transactions to its work plan. In the absence of specific standards for cryptocurrencies, and given that current IFRS standards were not designed with cryptocurrencies in mind, we can see forms of reporting based on cost or fair value, with gains or losses through other comprehensive income, rather than at fair value through profit or loss ([8]).

Without a specific standard regarding crypto assets, different professionals have different suggestions: crypto assets can be categorized into different types of assets, including intangible assets, cash equivalents, inventory, and financial instruments; additionally, crypto assets can be classified as either short-term or long-term assets ([9]). In this context, [10] have analysed the financial statements of 40 global companies with cryptocurrencies and highlighted the disparities between those that apply GAPP and those that apply IFRS, as well as distortions that can mislead users when assessing the value of assets, liquidity, profitability and cash generation capacity of different companies. The same kind of evidence was obtained by [4] when comparing Slovak and multinational solutions and [11] for the Czech Republic, the Slovak Republic, and the Federal Republic of Germany.

This lack of guidance is also reflected in the audit work. In addition to the associated risk, it is clear that carrying out an audit of crypto assets and related transactions requires different knowledge, methods, and approaches than other assets present in the financial statements ([12]). As stated by [13], auditors need a clear structure and guidance to audit financial statements reflecting the new issues, risks, and challenges of cryptocurrencies and crypto asset transactions. [[12], p. 130] conclude that "The auditors should increase their competence level in terms of accounting, auditing of crypto assets and related transactions through education and additional training, using the work of experts".

According to [14], the potential challenges that the accounting profession and the auditing profession could face as a result of the expansion of blockchain technology and cryptocurrency were not unknown to the various professional and regulatory bodies, nor the large auditing firms, the latter of which has been developing ways of dealing with these challenges. In reality, "the big four auditing firms started to develop their own solutions; provide assurance services to their auditees engaging in blockchain activities; and to support the auditing of cryptocurrency" ([[14], p. 66]). In addition, several regulatory

bodies such as the American Institute of Certified Public Accountants (AICPA) (in 2020) and Chartered Professional Accountants Canada (CPA Canada) (in 2018 and 2020) have released some guidance for auditors related to specific audit phases concerning crypto asset transactions ([13]).

Due to the diversity and constant innovation in this area, the facts and circumstances of each entity are different, making it very difficult to apply generic accounting standards. Given the lack of specific accounting standards for cryptocurrencies and the lack of auditing standards for this specific issue, professionals face numerous difficulties in recognizing and measuring cryptocurrencies. The lack of official accounting and auditing guidelines for crypto assets and related transactions imposes additional audit risks that should be properly assessed before the client acceptance phase and the audit planning procedures. Researchers play a special role in helping not only to alert regulators to the difficulties faced by accountants and auditors, but also to contribute possible solutions in terms of accounting for cryptocurrencies. This special role is also defended by [[8], p. 18] "Researchers can help in identifying and understanding how blockchain technologies and crypto assets are evolving and impacting the capital markets, organizations, and society".

3 Methodology

Following the guidelines of [15], this research used a bibliometric methodology to examine research on the impact of cryptocurrency adoption and the accounting and auditing professions. According to [15], bibliometric analysis stands out as an extremely robust approach to analysing extensive sets of scientific data, making it possible to understand the evolutionary path of a given field, and illuminating emerging trends and areas of interest. To investigate studies within the designated area of interest, a search was carried out on January 10, 2024 in ISI WoS and Scopus databases, using a combination of keywords, namely "Cryptocurrency" AND "Accounting" AND "Auditing".

The analysis was limited to articles and conference papers in the areas of Business, Management, Business Finance and Economics (ISI WoS database) and Business, Management and Accounting and Economics, Econometrics and Finance (Scopus database). The initial search did not have any time restrictions and resulted in 34 ISI WoS documents and 38 Scopus Scopus documents, which were then analysed using the bibliometrix package in the R software. A preliminary step led to the identification of duplicates, so that 5 documents were eliminated, resulting in a total of 67 documents. A more in-depth analysis of the documents found led to the exclusion of 12 documents that did not fit the theme, resulting in 55 documents for analysis. Of these 55 documents, 48 are articles published in journals and 7 are conference papers.

4 Analysis and Results

Table 1 presents the main information on the documents to be analysed in this study. We examined 55 relevant studies published since 2017 (date of publication of the first article in the databases), encompassing 36 sources and 121 authors, with an annual growth rate of publication of 58,74%. These studies, authored by a total of 121 individuals, exhibited

an average of 6,68 citations per document. A majority of authors contributed to multi-authored studies, while 11 authors were associated with single-authored studies. Also in Table 1, we can see that the median number of co-authors per document is 2,69 and the rate of international co-authorships is 3,636%.

Table 1. Data base description.

Description	Results
Timespan	2017:2023
Sources (Journals, Books, etc.)	36
Documents	55
Annual Growth Rate %	58.74
Document Average Age	2.67
Average citations per doc	6.618
Average citations per year per doc	1.682
References	654
DOCUMENT TYPES	
Article	47
Article; early access	1
Conference paper	2
Proceedings paper	5
DOCUMENT CONTENTS	
Author's Keywords (DE)	179
AUTHORS	
Authors	141
Author Appearances	148
Authors of single-authored docs	10
AUTHORS COLLABORATION	
Single-authored docs	11
Documents per Author	0.39
Co-Authors per Document	2.69
International co-authorships %	3.636

Note: Table1 presents the descriptive statistics of the 55 documents collected from WoS and Scopus databases, using a combination of keywords, namely "Cryptocurrency" AND "Accounting" AND "Auditing", in the areas of Business, Management, Business Finance and Economics (ISI WoS database) and Business, Management and Accounting and Economics, Econometrics and Finance (Scopus database), and analysed in this study

To analyse how accounting and auditing have faced the challenges resulting from technological evolution, namely digital currency, we can see from the information presented in Table 2 that this topic appeared for the first time in 2017, with an increase in research published in the WoS and Scopus databases, especially in the years 2022 (17 articles) and 2023 (16 articles).

Table 2. Annual scientific production.

Year	Articles
2017	1
2018	5
2019	2
2020	8
2021	6
2022	17
2023	16

Note: Table 2 presents the annual scientific production based on 55 documents collected from WoS and Scopus databases, using a combination of keywords, namely "Cryptocurrency" AND "Accounting" AND "Auditing", in the areas of Business, Management, Business Finance and Economics (ISI WoS database) and Business, Management and Accounting and Economics, Econometrics and Finance (Scopus database), and analysed in this study

This increase in publications, which has already been mentioned, represents an annual growth rate of 58.74%, and is boosted by various authors. The most productive authors with more than 1 article are presented in Table 3. Smith, S. is the most productive author, with 5 articles, 2 of which are single-authored docs and 3 co-authored. Next, we find Brennan, G., Hsieh, S. and Kinory, E. with 2 articles co-authored. When looking at the H_index and total citations presented in Table 4, Smith, S. is the most cited author, followed by Kinory, E., Brennan, G. and Hsieh, S.

However, when evaluating the productivity of authors' work, it is crucial to consider the significant role played by the h-index. In this regard, authors such as Smith, S., Brennan, G. and Hsieh, S. stand out with h-index equal to or greater than 2. Taking into account the time frame of each author's research, looking to distinguish new researchers from more experienced ones, we examined the m-index which provides a fairer measure of productivity for new researchers in the field. Brennan, G. and Hsieh, S. are authors demonstrating commendably high m-indices, surpassing 0,66 when compared to their peers, followed by Alsalmi, N. and Alles, M. with 0,50.

The 10 top manuscripts per citations are presented in Table 5. The article with the highest number of citations is "Blockchain in the accounting auditing and accountability

Table 3. Most productive authors

Authors	Articles
Smith S	5
Brennan G	2
Hsieh S	2
Kinory E	2
Abdennadher S	1

Note: Table 3 presents the most productive authors based on 55 documents collected from WoS and Scopus databases, using a combination of keywords, namely "Cryptocurrency" AND "Accounting" AND "Auditing", in the areas of Business, Management, Business Finance and Economics (ISI WoS database) and Business, Management and Accounting and Economics, Econometrics and Finance (Scopus database), and analysed in this study

Table 4. Most productive authors in terms of index and total citations

Element	h	g	m	TC	NP	PY_start
Smith S	3	5	0.4285714	54	5	2018
Kinory E	1	2	0.2500000	11	2	2021
Brennan G	2	2	0.6666667	8	2	2022
Hsieh S	2	2	0.6666667	8	2	2022
Abdennadher S	1	1	0.3333333	5	1	2022
Abdulla H	1	1	0.3333333	5	1	2022
Alfalasi A	1	1	0.3333333	5	1	2022
Alsalmi N	1	1	0.5000000	4	1	2023
Adelowotan M	1	1	0.2500000	2	1	2021
Alles M	1	1	0.5000000	1	1	2023

Note: Table 4 presents the most productive authors in terms of index and total citations based on 55 documents collected from WoS and Scopus databases, using a combination of keywords, namely "Cryptocurrency" AND "Accounting" AND "Auditing", in the areas of Business, Management, Business Finance and Economics (ISI WoS database) and Business, Management and Accounting and Economics, Econometrics and Finance (Scopus database), and analysed in this study

fields: a bibliometric and coding analysis", by Secinaro, S., Dal, M., F, Brescia, V. and Calandra, D., with 48 total citations. Also, with 30 citations and more, we find "Overview and Impact of Blockchain on Auditing" by Bonyuetd, D. (39 citations), "The disruption of blockchain in auditing – a systematic literature review and an agenda for future

research" by Lombardi, R., de Villiers, C., Moscariello, N. and Pizzo, M. (32 citations) and "Accounting for Bitcoin and Other Cryptocurrencies under IFRS: A Comparison and Assessment of Competing Models" by Procházkad, D. (30 citations).

Table 5. 10 most cited articles

Authors	TC	TC per year	NTC
Secinaros (2021), Accounting, Auditing & Accountability Journal	48	12.000	5.3333
Bonyuetd (2020), The International Journal of Digital Accounting Research	39	7.800	3.0891
Lombardir (2022), Accounting, Auditing & Accountability Journal	32	10.667	5.3861
Procházkad (2018), The International Journal of Digital Accounting Research	30	4.286	3.1250
Smith (2020), Journal of Emerging Technologies in Accounting	27	5.400	2.1386
Fuller (2020), Journal of Corporate Accounting & Finance	24	4.800	1.9010
Zemánková, (2019), WSEAS Transactions on Business and Economics	22	3.667	1.2941
Smiths (2018), Australasian Accounting, Business and Finance Journal	14	2.000	1.4583
McGuigan (2019), Meditari Accountancy Research	12	2.000	0.7059
Spanòr (2022), Accounting, Auditing & Accountability Journal	11	3.667	1.8515

Note: Table 5 presents the 10 most cited articles based on 55 documents collected from WoS and Scopus databases, using a combination of keywords, namely "Cryptocurrency" AND "Accounting" AND "Auditing", in the areas of Business, Management, Business Finance and Economics (ISI WoS database) and Business, Management and Accounting and Economics, Econometrics and Finance (Scopus database), and analysed in this study.

Figure 1 presents the most relevant sources. We find 5 articles published in the journals "Financial and credit activity: problems of theory and practice" and "The International Journal of Digital Accounting Research" and 2 of the 10 most cited articles were published in this last journal. The "Economic Annals-XXI – International Research Journal" and the "Journal of Emerging Technologies in Accounting" published 4 articles and the "Accounting, Auditing & Accountability Journal" has published 3 articles, all three belonging to the 10 most cited articles.

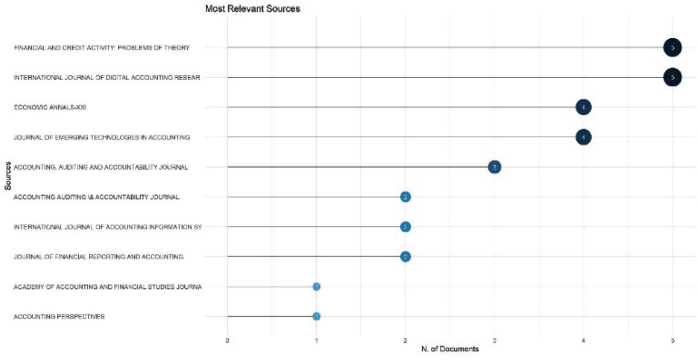

Fig. 1. Most relevant sources

Regarding the 10 most frequent authors keywords, we find that Accounting is more frequent than Auditing. Most studies analyse the relationship of accounting and/or auditing not only with cryptocurrencies but also, more broadly, with Blockchain, Blockchain technology and Digitalization (Table 6).

Table 6. 10 most use keywords

Terms	Frequency
Accounting	31
Blockchain	28
Cryptocurrency	23
Auditing	14
Bitcoin	8
Blockchain technology	5
Cryptoassets	4
Digitalization	4
IFRS	4
Smart contracts	4

Note: Table 6 presents the 10 most used keywords based on 55 documents collected from WoS and Scopus databases, using a combination of keywords, namely "Cryptocurrency" AND "Accounting" AND "Auditing", in the areas of Business, Management, Business Finance and Economics (ISI WoS database) and Business, Management and Accounting and Economics, Econometrics and Finance (Scopus database), and analysed in this study.

We also present in Fig. 2 the three fields plot highlighting the relation between the authors, countries and keywords. It should be noted that most of the authors are of American and Ukrainian origin, with only one work by Portuguese authors.

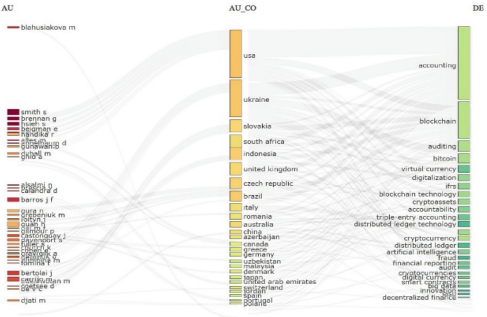

Fig. 2. Authors, countries and keywords relation

The articles analysed show a very strong focus on describing the characteristics of blockchain technology and the impact of blockchain on accounting and auditing. Concerning the specific problem of possible ways of accounting for cryptocurrencies and selecting the most appropriate criterion, we found 23 articles. The most cited article is "Accounting for Bitcoin and Other Cryptocurrencies under IFRS: A Comparison and Assessment of Competing Models" by David Procházka, with 30 citations. [6] seeks to address the lack of specific guidance on how cryptocurrencies should be accounted for in the financial statements of entities that use them. The author compares and evaluates potential accounting frameworks under IFRS, concluding that fair value accounting emerges as the most pertinent source of valuable information for users of financial statements, especially when cryptocurrencies are acquired for investment purposes.

Next comes the article by Paola Ramassa and Giulia Leoni entitled "Standard setting in times of technological change: accounting for cryptocurrency holdings" with 7 citations. [3] focuses on the International Accounting Standards Board's (IASB) approach to the evolving challenge of accounting for cryptocurrencies and conducts a survey seeking to analyse stakeholders' expectations and the driving forces behind its regulatory actions in this area.

We believe it is also important to highlight the works of Noora Alsalmi, Subhan Ullah and Muhammad Rafique entitled "Accounting for digital currencies" and Eyal Beigman, Gerard Brennan, Sheng-Feng Hsieh and Alexander J. Sannella, "Dynamic Principal Market Determination: Fair Value Measurement of Cryptocurrency", both with 4 citations. [1] also state that current accounting standards do not precisely cover the accounting treatment of digital currencies and identify the need for an accounting standard that guides the identification, classification, measurement and reporting of cryptocurrencies and digital currencies. The authors also point out that until such a standard is issued, existing accounting standards can be amended to incorporate digital currencies to avoid inconsistent global accounting approaches. [16] consider that due to the fragmentation of cryptocurrency markets and the widespread dispersion of trading platforms around the

world, identifying a principal market can present significant challenges. The authors are mainly concerned is presenting a methodology for dynamically determining the cryptocurrencies principal markets and obtaining fair value prices for financial reporting purposes, using principal markets designation.

In the area of financial auditing related to the specific case of cryptocurrencies, there is still little research to be found. The most cited article is "The effects of blockchain technology on the accounting and assurance profession in the UAE: an exploratory study" by Sonia Abdennadher, Rihab Grassa, Hareb Abdulla and Abdulla Alfalasi. Due to the government's implementation of blockchain technology in the United Arab Emirates. [14] decide to analyse the perceptions of accountants and auditors and conclude that blockchain changes the audit process and strategy. The blockchain has great potential to complement traditional auditing by providing a decentralized, low-cost auditing process and automated audit evidence. The majority of respondents highlighted the development of assurance services for clients involved in blockchain and cryptocurrency activities. But on the other hand, there was a sense of pessimism around this development and how blockchain technology will affect the operations of audit firms.

Also worth mentioning is the work of Sheng-Feng Hsieh and Gerard Brennan, "Issues, risks, and challenges for auditing crypto asset transactions". [13] highlight various assurance options, including assurance on smart contract code, audits of oracles and blockchain protocols, and continuous auditing, which auditors can follow once they have addressed relevant conceptual and technical considerations.

5 Conclusions

Accounting and auditing cryptocurrency transactions pose substantial challenges in terms of valuation, regulatory compliance, and transparency. Overcoming these challenges requires cooperative efforts among standards bodies, regulators, industry participants, and accounting and auditing experts to develop comprehensive guidance and standards that accommodate the distinctive attributes of cryptocurrencies, while maintaining transparency and accountability in financial reporting. This article aimed to deepen and evaluate existing research on the use of crypto assets in accounting and auditing. It employs a bibliometric analysis of articles focusing on cryptocurrency in the accounting and auditing domains.

The analysis reveals the general notion of accounting regulators' struggle to establish accounting standards for cryptocurrencies, given that the existing standards are not suitable for this situation, and emphasises that the impact of crypto assets in auditing is still at an early stage. The research related to the accounting and auditing of cryptocurrency transactions is still exploratory, and more empirical inquiry is needed. Additional research is needed to explore how auditors can effectively determine the extent and risks associated with digital currency transactions during audit planning and evidence gathering. This investigation is essential to ensure that auditors can provide reasonable assurance as to the absence of material misstatements in the financial statements. Our evidence indicates promising areas for future research efforts within the academic community regarding the use of crypto assets. The impact of the use of crypto assets on accounting and auditing still needs further research and clearer guidance from regulatory bodies.

Also, from our study comes the recommendation for accounting regulators to prioritise the issuing of international accounting standards, both in the field of accounting and auditing, which will not only guarantee a normalised treatment of cryptocurrency transactions but will also guide auditors when auditing these assets.

This paper is relevant because it reviews the current literature, consolidating and structuring information regarding accounting and auditing issues regarding cryptocurrency transactions. It offers a valuable perspective on the undergoing research and encourages the exploration of new research directions in this area.

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Challenges of Artificial Intelligence in the Accounting Profession

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Abstract. Artificial intelligence has revolutionized accounting processes and procedures, making them more effective and agile. The ability to perform tasks, previously restricted to humans, is challenging accountants to redefine their professional roles. This study aims to analyze the artificial intelligence systems adopted by companies and explore accountants' adaptation to this new professional paradigm. The research covers the challenges arising from their implementation in accounting and the profession's prospects. The paper is based on an empirical study conducted with Portuguese companies in the industrial sectors, using quantitative analysis. The results show a tendency to adapt to artificial intelligence, indicating that accountants are prepared for a constantly evolving professional environment. In this context, there is a clear emphasis on developing analytical, management, and computer skills to add value to organizations. This paper highlights the imminent transformation of accounting driven by artificial intelligence, charting a path where cooperation between technology and human skills is the key to professional excellence in the ever-evolving technological landscape.

Keywords: Accounting · Artificial Intelligence · Enterprise Resource Planning · Blockchain · ChatGPT

1 Introduction

In recent years, the intersections between technology and accounting have become increasingly prominent, with the rise of artificial intelligence (AI) as a key driver of this change. Incorporating AI technologies into the accounting profession has triggered profound transformations, redefining how accountants conduct their activities. The development of this subject raises the need for a comprehensive analysis to understand the implications and opportunities that AI brings to the accounting field.

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The growing presence of AI in various domains of society raises fundamental questions about how traditional professions will adapt to this new paradigm. In the accounting context, this technological evolution not only offers significant advantages but also requires professionals to be prepared to embrace change and extract maximum benefit from it.

This work explores and analyzes the relationship between AI and accounting. The basis of the research is to understand the evolution of accounting practice with the introduction of AI systems, as well as to analyze how accountants are dealing with challenges in a changing professional environment and how they are adapting to this new technological paradigm. As AI continues to shape the context of accounting, the ability to adapt and harness the value of emerging technologies will be critical to maintaining the importance of accountants in the profession.

The results reveal a trend towards integrating these technologies, specifically in optimizing processes through enterprise resource planning (ERP) systems. The analysis highlights the main concerns of implementation costs and dependence on AI experts. The future of the accounting profession is signaled by a positive perception and a willingness to adapt. Some reports indicate an evolution towards data analysis and the development of analytical skills, while others emphasize the need to improve technological skills to keep up with ongoing changes.

The work is structured into five sections. After the introduction, section two presents the literature review addressing the adaptation of AI systems in accounting and the future of accounting, highlighting accounting skills. The methodology, results and discussion are then presented. The paper ends with conclusions and suggestions for future research.

2 Artificial Intelligence Systems in Accounting

Accounting plays an essential role in the context of the economy, contributing significantly to decision-making and the sustainable growth of businesses and countries.

Aiming for more efficient processing of information, accounting has undergone gradual changes to improve the performance of responsibilities, services, processing and data analysis, thus meeting both internal and external needs [1]. What two decades ago was considered a task to be performed by accountants, is today carried out through AI systems and accountants have begun to explore the field of analysis and interpret data, to communicate this information to top managers to help with decision-making [2].

AI is a branch of science and technology that creates intelligent machines and computer programs capable of performing various tasks that require human intelligence, thus imitating the various functions performed by humans and achieving excellent performance in these tasks [3]. AI focuses on the specific functionality of intelligence, which is finding patterns. Just like human intelligence, algorithms that mimic the brain are needed [4]. To achieve this, AI must have access to patterns, which requires data collection. This data is generated from human past experiences, adaptation to new situations and use of knowledge to generate new ideas. The amount of information needed for machines to learn to act intelligently and artificially has doubled over the years. In the field of accounting, the application of AI systems is mainly based on machine learning [5].

The accounting profession has followed the evolution of AI systems and incorporated advanced AI systems, such as ERP systems, Blockchain technology, natural language processing (NLP) models such as ChatGPT and voice recognition systems, among others. The implementation of these AI systems has facilitated many accounting activities and processes. [6] lists some of these accounting activities and processes related to the creation, organization, use, management, and control of the accounting information system, which has been simplified with technological innovation and the introduction of AI. Among them, we highlight:

(1) Improvement in documental organization and archiving: AI uses ideal methods of collecting and storing data and accounting information, allowing automatic classification and documental organization. Furthermore, accounting data and information are stored securely and efficiently. This approach results in greater effectiveness of the accounting profession, avoiding the loss of documents that could occur in a paper-based accounting environment.
(2) Support for the acquisition of knowledge and skills by employees: AI offers support to employees through a knowledge base. This helps in acquiring skills and knowledge in information and data processing, facilitating the learning and professional development of employees. With this support, employees can handle complex and challenging accounting tasks.
(3) Providing consultancy services and simulating specific scenarios for decision-making: AI's ability to deal with large amounts of financial data allows for more accurate reports and financial statements. This supports the accountant in providing consultancy services, providing reliable information and simulations of specific scenarios that help clients make decisions.

Intelligent systems allow accountants to solve three major problems: providing decision-making support, more accurate, sensible and accessible data, detailed data analysis and new insights into the business [7]. Traditional accounting processes, such as accounting records and preparing financial statements, require a lot of attention from professionals and, when combined with deadlines to be met, can lead to errors caused by fatigue. With the use of accounting software, a large part of these processes becomes automated, which is facilitated by the fact that accounting is a more routine and time-consuming profession [7], avoiding errors and improving the quality of the accounting information [10], resulting not only in greater data accuracy but also in time savings [7].

With the implementation of AI systems in accounting, the question of the need for accountants to perform their functions arises. According to [8], more experienced accountants at large companies argue that the demand for human accountants will not disappear anytime soon. This is because AI technologies are intended to replace specific tasks within the profession, rather than the profession as a whole [2].

[9] demonstrated the positive impact of AI and systems used in accounting on the profession. Therefore, it becomes increasingly urgent for accountants to be up to date with relevant technologies for the profession, to keep up with developments in the field.

Faced with the threat of job losses due to the introduction of AI systems, accountants need to adapt efficiently and effectively to keep up with AI-driven advancements in the profession. As stated by [9], knowledge of technological systems is crucial, as it will enable accountants to perform various functions with the help of these systems.

To adapt effectively to the changes resulting from this scenario, accountants must acquire several skills, such as professional skills, management skills, information technology (IT) skills, analytical skills, and decision-making skills [9].

In the field of accounting, there is constant evolution in accounting standards, tax legislation and procedures, making it important that the professional skills of each accountant are up to date, thus guaranteeing the quality of work and monitoring changes in the profession.

Learning management skills is increasingly relevant for accountants. With accounting processes automated by AI systems, there is a need to expand professional activity, for example, in financial manager positions or functions that involve management, increasingly explored by accountants.

Computerization is increasingly present in the accounting profession. Therefore, it is recommended that accountants not only master basic computer operations but also have knowledge of programming techniques that can improve their data processing skills. Furthermore, [10] addresses the perspective of how AI systems can present new challenges and specific issues that can only be resolved through human involvement, which will play a key role in solving unique problems, interpreting results and exercising professional judgment. Collaborating with accounting firms and suppliers to develop new AI technologies and support existing systems represents a promising area for accountants to explore [2]. The accountant is responsible for monitoring the use of intelligent machines in accounting procedures [2]. In this way, accountants' ability to understand and use IT, combined with their analytical and interpretative skills, plays a crucial role in effectively adapting to the demands of the accounting profession in an increasingly technological environment.

Accounting professionals are responsible for examining an extensive range of financial information through financial statements and reports. In this context, improving competence in analyzing and interpreting financial results is essential to assess and analyze risks in a coherent, precise, and efficient way, and subsequently communicate this information to managers and boards of directors [2].

The ability to be able to evaluate efficiently and effectively the quality of a project, identify the tools necessary for its execution and make decisions quickly is also a point that can be explored by the accountant to improve their knowledge.

In addition to these skills, it is also important to have the skill to predict and monitor future economic trends, as well as the degree of risk for any company. This will allow managers to recognize the value they add to the company and, consequently, to the accounting, ensuring the relevance of the accounting professional in providing financial information. Accountants must be ready to actively adapt their thinking process, abandoning the traditional accounting function, to adjust to current trends and make accurate predictions about the present and future economic prospects of several companies [9].

Furthermore, some activities AI systems are not yet capable of performing, such as attracting customers, which makes the human role indispensable in this context [2].

By developing such skills, accounting professionals will be able to play a strategic and essential role within organizations, contributing to the financial success of companies and preserving their relevance in a constantly evolving environment. In this context, it is important to highlight that, although AI systems are transforming the accounting

profession by automating specific tasks, accountants must adapt and improve their skills to remain valued and perform strategic functions that cannot be replaced by AI. The human component remains indispensable in areas such as decision-making, analysis, interpretation, and customer relationships.

AI in accounting represents a revolution in the field, bringing significant advantages and considerable challenges, such as the increasing cybersecurity risk, the implementation costs, the difficulty in adapting to new working conditions with the suppression of work posts and the resistance to change, particularly of older professionals [18]. The ability of accountants to adapt and develop relevant skills will determine their continued role as valuable professionals in a constantly evolving accounting environment, where the human component continues to be indispensable for decision-making, critical analysis and client relationships.

3 Method

This study is based on perceptions regarding the integration of AI systems in accounting. The main purpose is to analyze the challenges faced by companies resulting from the integration of AI systems into accounting practices, exploring perspectives, attitudes and experiences regarding the adoption and implementation of these innovative technologies.

Based on this central objective, the following research questions were formulated:

What are the challenges of using AI systems in accounting?

What is the impact of using AI systems on the future of the accounting profession?

The sample was selected from the SABI database (Iberian Balance Sheet Analysis System) and covered Portuguese companies from industrial sectors, with operating income in 2022 of more than €15,000.

The selection process resulted in a final sample that covered a total of 475 companies, where 53 responses were obtained, representing approximately 11.16% of the total sample.

Data collection was carried out using a structured questionnaire, sent in 2023, using open and closed questions. It also used the Likert scale of 1 to 5, where 1 is "totally disagree" and 5 is "totally agree". To analyze the results, the IBM SPSS (Statistical Package for the Social Sciences) software was used.

4 Results and Discussion

4.1 Use of ERP Systems and Complementary AI Systems

The results of the questionnaire show that all companies use ERP systems to support accounting, with 66% using them for more than 10 years. The most used ERP is SAP (62%), followed by Oracle (21%) and Sage (19%). In addition to these, other systems such as Primavera, PHC Software and TOC Online were mentioned.

The financial management module is widely used by all companies, which suggests the significance of financial management in accounting, as well as the importance

of automating and optimizing these processes. In addition, the most used modules are human resources management (90.5%), stock management (88.6%) and sales management (86.7%). Production and manufacturing management and project management modules appear less frequently. These results prove the trend toward the comprehensive integration of ERP systems in the accounting activities of the participating companies.

Regarding the adoption of AI systems to complement ERP systems, the responses present a diverse range of approaches and allow us to more deeply understand the AI technologies that are being incorporated to improve accounting practices (Fig. 1).

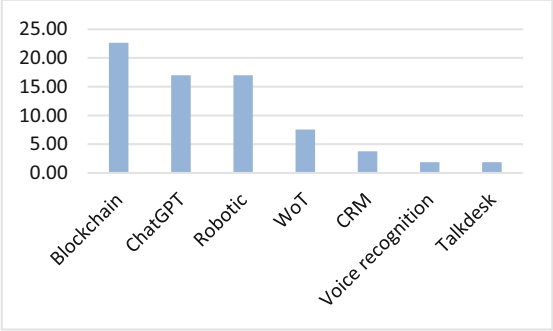

Fig. 1. AI systems complementary to ERP (%)

The blockchain represents the preferred AI system for 23% of companies. This suggests considerable recognition of the advantages of ensuring the security and integrity of accounting data [11].

The use of Robotics (17%) and ChatGPT (17%) indicates considerable interest for companies to adopt automation to optimize accounting processes and use NLP systems for communication and support in accounting decision-making.

The respondents also point to the use of other technologies, such as the Web of Things (WoT) and voice recognition systems. These highlight an even greater diversity in strategies for integrating AI into accounting, demonstrating companies' willingness to explore a wide range of technologies to improve their accounting operations.

Specific technology choices can be aligned with individual company needs and compatibility with implemented ERP systems. This variety of approaches highlights the flexibility of companies in adopting AI technologies that best fit their operations and accounting purposes.

4.2 Challenges of Artificial Intelligence Systems in Accounting

This section analyzed the challenges arising from the use of AI systems, namely: difficulty in adapting and learning AI systems, costs associated with the implementation and maintenance of AI systems, dependence on AI experts to operate the systems, security concerns and privacy of accounting data and concerns on accounting profession extinction.

When evaluating the responses related to the difficulty in adapting and learning AI systems, it is possible to observe that 71.6% of companies are in line with the view of [12] that AI systems require a process of careful implementation, as well as the acquisition of appropriately qualified personnel [13]. Still, the options "disagree" (3.7%) and "neither agree nor disagree" (24.5%) were chosen by a smaller number of companies, suggesting that some companies have a more optimistic view regarding the ease of adaptation and learning of AI systems. In contrast, others may have a neutral perspective.

Through analysis with SPSS, it was found that companies that use AI in addition to ERP systems face greater challenges in adapting to these systems (with 14.3% agreeing and 64.3% completely agreeing) compared to companies that do not use it (64%). These variables are correlated, indicating that the more AI systems a company adopts, the greater the difficulty in adapting to these systems, as demonstrated by Pearson's Chi-square test with a significance level of 0.011.

Regarding the costs associated with implementing and maintaining AI systems, it was observed that most companies agreed with this disadvantage, whether in the "agree" option with 73.5% of responses or "completely agree" with 20.7% of answers. This indicates that companies are aware of the financial challenges associated with the adoption of AI systems, a disadvantage also mentioned by [14]. Despite this, a smaller number of companies opted for the "disagree" (1%) and "neither agree nor disagree" (3%) options, which may be related to the ease with which these companies have in acquiring such AI systems, combined with the benefits it entails.

Concerning dependence on AI specialists for the operation of systems, it was possible to verify that the predominant responses were the "agree" and "completely agree" positions at 58.5%, with a portion of companies having a neutral opinion with this disadvantage (39.6%) or disagreeing (1.9%). This suggests that, in general, companies perceive that it is important to have qualified personnel, such as [13] study, to guarantee a productive and efficient use of AI systems.

In the case of concerns about the security and privacy of accounting data, the responses demonstrate a wide distribution of opinions across companies. Some companies expressed disagreement (3.7%), while others (20.7%) opted for a neutral position. Despite this, a considerable number of companies agreed or completely agreed (37.7% responses each) with this concern, representing 75% of the companies.

Using SPSS, it was possible to conclude that companies that incorporate AI systems into accounting, in addition to ERP systems, demonstrate greater apprehension regarding the security and privacy of accounting data (85.7%) compared to those that do not adopt (64%). However, it is important to highlight that no statistical significance was found in the relationship between the adoption of AI systems and concerns about the security and privacy of accounting data.

This distribution of responses suggests that Portuguese companies are aware of security and privacy concerns, corroborating [15], and the need to adopt appropriate measures to protect their data against possible security breaches, like the study of [16].

Finally, on the topic of concerns about the extinction of the accounting profession, more diverse responses were obtained. At one extreme, 16.9% of responses were obtained, with 5.6% of companies completely disagreeing and another 11.3% of companies disagreeing. At the other extreme, 33.9% of companies share the same opinion as

[17] that the risks related to the possibility of the accounting profession being affected by AI are real. Despite this, most companies (49%), presented a neutral opinion regarding this aspect, suggesting a more optimistic perception or perhaps confidence in the unique skills and knowledge that accounting professionals bring to the field, despite the introduction of advanced technologies.

Complementing the analysis with SPSS, it was found that companies that incorporate AI systems in addition to ERP show greater concern regarding the possible extinction of the accounting profession (39.2%), compared to those that do not adopt this approach (28%). However, it is important to highlight that Pearson's Chi-square test revealed the lack of statistical significance in the relationship between the use of AI systems in addition to ERP systems and concern about the extinction of the accounting profession.

Furthermore, when relating the size of the company to the concern about the extinction of the profession, it becomes clear that medium-sized companies (18.2% agree and 22.7% completely agree) are more apprehensive about the future of the profession compared to large companies (6.5% agree and 22.6% completely agree). However, it is important to note that, once again, no statistical significance was identified, as indicated by a p-value of 0.752.

Additionally, concerns about the extinction of the profession may be related to the automation of accounting tasks through AI. It was observed that 71.4% of companies that maintain a neutral position on the automation of accounting tasks with the introduction of AI are more concerned about the extinction of the profession. On the other hand, 50% and 7.4% of companies that agree and strongly agree, respectively, that AI has brought automation to the accounting profession, are also concerned about its future. This correlation between the automation of accounting tasks with the introduction of AI and accountants' concerns about the future of the profession was confirmed by the Pearson Chi-square test, presenting a significant value of < 0.001.

In addition to the previous disadvantages, one company highlighted an additional concern in its open-ended responses: the technical glitches that can occur when using AI systems in accounting. The company mentioned that while the implementation of AI brings efficiency and automation, the occurrence of technical glitches can have a significant impact. These technical failures can result in interruptions in accounting operations, forcing professionals to suspend work until the technical issue is resolved. This perspective raises a valid point about the risks associated with reliance on advanced technologies, which can sometimes result in unexpected setbacks. Concern about technical failures reinforces the importance of considering not only the benefits but also the vulnerabilities inherent to the adoption of AI systems in accounting.

4.3 Future of the Accounting Profession

The evolution of the accounting profession has generated considerable debate due to the growing influence of AI and other technologies on the accounting field. In this context, respondents revealed a variety of perspectives on the direction of the accounting profession due to the increasing integration of AI into accounting practice.

The predominant view among the respondents (22.2%) is that the future of the accounting profession is intrinsically linked to data analysis. The ability to interpret and analyze large volumes of information is identified as a fundamental skill that accountants

must develop to remain relevant. This point of view is in line with previous studies that emphasize the role of accountants in extracting valuable information from data generated by AI systems [9].

Alongside this perspective, there is the perception that accountants will play an important role in decision-making. This suggests that the profession will not only focus on analyzing data but also on the use of these analyses to guide financial strategies and choices [2, 9].

In addition to this point, the need for accountants to develop technological skills was highlighted in 5.6% of responses. Companies recognize that the accounting profession must evolve to embrace emerging technologies, such as AI, and acquire skills that allow them to collaborate effectively with these technologies. This reflects an understanding that AI will not completely replace accountants, but rather will transform the nature of their work, requiring a more technologically adept mindset [2].

In general, the responses reflect a balanced perception of the future of the accounting profession in the context of AI. While the automation of specific tasks is recognized, there is an awareness that accountants must adapt and develop new skills to perform strategic and data analysis roles. This validates the perspectives of the literature, which emphasize that AI will not eliminate the profession, but rather redirect its functions and responsibilities, maintaining the fundamental human element in accounting [2, 7, 9].

5 Conclusion

This work focuses on the challenges of AI in the accounting profession, based on an empirical study of Portuguese companies from industrial sectors. Thus, identify concerns such as difficulty in adapting and learning AI systems, costs associated with the implementation and maintenance of AI systems, dependence on AI experts to operate the systems, security concerns and privacy of accounting data and concerns on accounting profession extinction.

The study highlights costs associated with the implementation and maintenance of AI systems and the security and privacy of accounting data. These concerns are in line with the research conducted by [15, 16, 18], which emphasized the challenges in ensuring the safeguarding of financial data.

Some companies did not show concerns about the future of the profession, pointing to its evolution towards data analysis, the development of analytical capabilities, and the importance of developing technological skills to keep up with the volatile environment. More than a third of companies expressed concerns about the challenges that the future could bring to the accounting area, corroborating the study of [17].

This study has limitations such as the subjective nature of respondents, which may be affected by individual biases and personal interpretations. Furthermore, the sample, although comprehensive, may not fully represent the diversity of companies present in different industries and regions. The relatively restricted number of responses may also impact the generalizability of the conclusions.

Future research may detail specific sectors to gain more accurate insights into how AI is being adopted and perceived by these sectors. Furthermore, it is important to study how education and training programs for accountants are evolving to prepare future

professionals to face emerging technological challenges. Given the growing importance of accounting data security, future research can also focus exclusively on the security measures adopted by companies. This may involve a detailed assessment of data protection best practices and how companies implement them in an environment that is increasingly technology-driven and susceptible to cyberattacks.

These suggestions for future research serve as a guide for the academic and business community, guiding understanding and adaptation to the ongoing impact of AI on accounting and the profession. As companies continue to adopt AI systems in accounting, professionals in this field must be prepared to face the challenges and take advantage of the opportunities this technology has to offer. Collaboration between human capabilities and AI advantages is key to ensuring excellence in accounting practices and ensuring that accountants remain essential assets in modern organizations.

The future of the accounting profession, guided by AI, offers a path full of opportunities, where the constant updating of skills and strategic adaptation will be essential to ensure the success and continued relevance of accounting professionals.

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Evaluating the Impact of Smart Contracts on Public Transportation: A Systematic Literature Review

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Abstract. The exponential growth of urban populations presents pressing challenges for public transportation systems worldwide. Among the myriad issues, traditional public transportation systems face a multitude of challenges, from inefficiency to safety concerns. The centralized nature of these systems exacerbates these issues, leaving commuters frustrated and cities gridlocked. However, Blockchain and Smart Contracts present an alternative paradigm, one that promises to disrupt the status quo and usher in a new era of urban mobility. In this comprehensive study, we conduct a systematic literature review to explore the transformative potential of Blockchain in the public transportation sector. By analyzing both its advantages and challenges, we pave the way for future research on this topic.

Keywords: Blockchain · smart contracts · public transportation · urban mobility · literature review

1 Introduction

The rapid population growth in cities is causing the need to improve the quality of life, enhancing the development of a sustainable environment with a better transportation infrastructure [1], and the necessity to improve transportation coordination, decreasing congestion [2]. Travelers often look for an efficient and punctual public transport system. However, this is one of the main problems [3]. Another challenge to face is public transport security [4]. The introduction of Blockchain in smart cities could be a way to enhance the quality of life of people in specific sectors like public transportation [5]. In recent years, a higher interest exists in research about Blockchain in transportation [6]. Previous articles consider the necessity of development studies related to blockchain applications in the context of public transportation [7]. Besides, earlier works focused on developing new business models integrating Blockchain and Artificial Intelligence

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(AI) in the context of the transportation sector [43]. In this situation, our paper intends to investigate the impact of Blockchain technology on public transportation. Furthermore, it also details several cases of implementing Smart Contracts and implications in the transportation sector. In this manner, it fills the gap because no previous work is focused on it. The principal research questions established in our work are as follows: What are the principal advantages and challenges related to the application of Blockchain in public transportation, and what practical implications it may have? To answer these research questions, this research aims to accomplish the main objectives: 1) to explore the potential of Blockchain in the public transportation sector and 2) to identify specific implications of the use of this technology in the sector. To achieve the response to these questions, a systematic literature review (SLR) was conducted.

2 Theoretical Background

2.1 Blockchain

Blockchain is a decentralized ledger system with a list of blocks where several computers validate them by encrypting the data [8]. It is an innovative, valuable technology for generating Smart Contracts and could improve the security and trust of businesses in any industry [9]. Moreover, Blockchain could facilitate the creation of decentralized identity management systems, guaranteeing the transparency and security of sensitive user data [10]. In 1991, Stuart Haber and Scott Stornetta created a cryptographically secure Blockchain to certify documents so no one could modify them [11]. Although Stuart and Scott created that system, they did not apply it, so it considers three stages in the evolution of Blockchain since its first application in 2008. The first stage began in 2008 [12] with the birth of the cryptocurrency called Bitcoin, whose operation is based on Blockchain technology [13]. The second stage appeared in 2014 with the introduction of Ethereum, which facilitates the creation of Smart Contracts and Decentralized Applications (Dapps) [14]. The third stage was born with consensus mechanisms like Proof of Stake (PoS) to solve issues like efficiency, interoperability, and environmental Sustainability caused by the Proof of Work (Pow) [5]. The PoW needs a large quantity of energy because it is necessary for the consensus of the majority of computers to validate the transactions (51%). In contrast, PoS only needs those with the most quantity of cryptocurrencies [8].

2.2 Smart Contracts

In 2014, it started using Smart Contracts, which were proposed by Szabo in 1995. It defines contracts executed when certain conditions are met [15]. For a Smart Contract to be completed, a negotiation of the conditions and specifications between the parties is necessary. Subsequently, the contract code is verified and obtained. Smart Contracts work through Blockchain. That is, they are stored in blocks. To do this, the computer nodes are responsible for validating the contracts by calculating the hash code based on the previous one. This means that we do not need a central node or intermediaries, reducing costs and increasing the efficiency of the processes. The Smart Contract is

confirmed and registered in the block when the nodes reach a consensus. At that point, no modification can be made to reinforce the immutability of the transactions. Platforms like Ethereum and Hyperledger have a Turing-complete programming language that allows Smart Contract development [13].

Smart Contracts could generate better transparency and security on public transportation systems by creating crypto tickets that generate appropriate privacy for users, so your data is only known by the Transportation Service Providers (TSP) [16].

2.3 Public Transportation

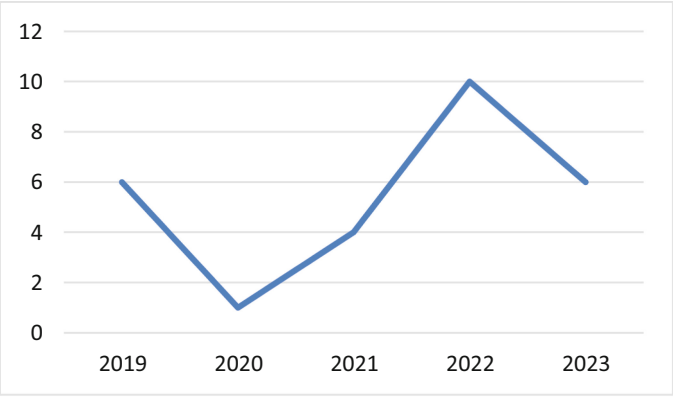
Public Transportation is a collective means of transportation into the city (e.g., urban transport like bus, train, metro, and tram or share taxis) or between cities (e. g. high-speed rails, airlines, coaches, and ferries) [17]. Two of the most typical concerns in cities are decreasing car use and reducing the impact of transport networks on the environment. To achieve this, good public transport management is essential for urban development. However, public transport still faces several sustainability challenges in its three dimensions – economic, social, and environmental [18]. It is believed that technological development could generate various benefits for cities, highlighting the improvement of Sustainability by reducing carbon dioxide emissions, improving active mobility, increasing efficiency, and saving time and costs in travel. Technological and disruptive innovations such as automated vehicles (AV) have been created to improve the urban transport sector [19]. AVs are usually cheaper because no driver is necessary. One way to improve traffic management could be to implement on-demand services. In addition, in the future, it is expected that the creation of services such as AV taxis will allow improvements in traffic management [20]. Intelligent Transportation Systems (ITS) are being developed in smart cities to introduce improvements in public transport infrastructures by improving mobility, safety, efficiency, and comfort. However, these systems are often vulnerable to malicious attacks, so security and privacy are their main issues. In addition, it is necessary to study more about the application of AI and Machine Learning (ML) to help detect and mitigate these security threats in these systems [21]. ITS usually focuses on real-time parking management, traffic management, or electronic pay. However, ITS could have data security problems that could be solved with a Public Blockchain-envisioned Secure Communication Framework for TS (PBSCF-ITS) [22]. Introducing Blockchain in public transportation permits increased safety and transparency by employing standardized travel credentials, enabling their use in Europe [10].

3 Methodology

A SLR was conducted, accomplishing the PRISMA (Preferred Reported Items for Systematic Reviews and Meta-Analysis) checklist to resolve the research questions. SLR enables the study of an emerging topic with potential for future academics [23]. To perform this SLR, on the 8th of October of 2023, it realized the following query in the Web of Science Database: TS = ((“blockchain” OR “distributed ledger” OR “smart contract*”) AND (“public transport*”)) In the first step, this search obtained 27 results, given the scarcity of research related to this field. The query contains English articles

and conference papers from 2019 to the present. The second step eliminates five articles (2 duplicates) that do not include the topic's words in their titles, abstracts, or keywords—the third step results in 20 papers, excluding works unrelated to the field. The articles have been carefully read. In future research, other bibliometrics could include more databases.

Table 1. Evolution of the publication



As can be seen, Table 1 shows the evolution of the papers related to the field. Since 2021, there has been a growing interest in investigating this topic; it is possible that the reason was the restrictions of mobilities caused by COVID-19 and the congestion and issues of Sustainability like CO2 emissions (Fig. 1).

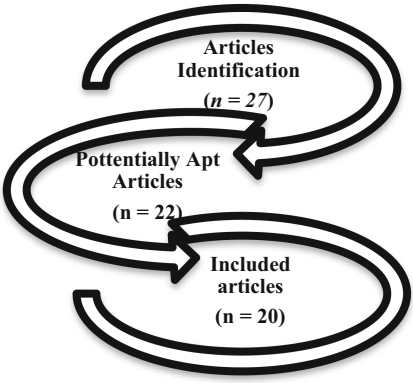


Fig. 1. PRISMA.

4 Results

The result sections contain the advantages and challenges of implementing Blockchain in public transportation.

A. **Advantages of the use of Blockchain in public transportation**

Concerning the advantages of the application of Blockchain on public transportation, it highlights the following:

a) Data Security, Transparency, and Trust: Using an encrypted hash code improves the data security, transparency, and trust between the users [24].
b) Better Digital Identification of the users and traceability of the baggage [25].
c) Safety and Fast Payments with Cryptocurrencies: Payments with cryptocurrencies increase security and faster-eliminating intermediaries [25].
d) Smart Contracts eliminate intermediaries: Smart Contracts record fast, transparent, and secure contracts [25].
e) Loyalty Programs: Public transportation users could receive rewards for their utilization [25].
f) Use of Decentralized Applications (DApps): Through a ride-sharing decentralized application, it is possible to grow the level of vehicle occupancy when people share the same workplace. These applications enable to pay with cryptocurrencies and maintain personal data privacy. This situation allows fewer vehicles, reducing pollution and energy consumption [26] (Table 2).

Table 2. Advantages of blockchain in public transportation.

Applications	Advantages	Authors
Hash encrypted	Improves data security, transparency, and trust	[24]
Digital Identification	Better identification and monitorization	[25]
Payment with Cryptocurrencies	Safety and fast	[25]
Smart Contracts	Eliminates intermediaries and Increase security, fast, and transparent transactions	[25]
Loyalty Programs	Generates rewards for the use of public transportation	[25]
Dapps	Decrease pollution and energy consumption	[26]

B. **Challenges of implementing Blockchain in public transportation**

Regarding the challenges of the introduction of this technology in this field, it could show the following:

a) Energy: Since using consensus mechanisms such as PoW usually requires much energy, using PoS would be more advisable [25].

b) Scalability: Blockchain could have problems like scalability [27]. Considering that the higher the number of contracts, the more issues like scalability could arise. It could develop a system with more scalability, enabling the aggregation of a more significant number of contracts [28].
c) Speed: With the increased transactions, the network could become slow [25].
d) Confidentiality: It is necessary to improve and protect the data and the users' privacy [31].
e) Legislation of the countries: Some countries prohibit the use of cryptocurrencies, so it is necessary to know the regulatory framework of each country [26] (Table 3).

Table 3. Disdvantages of blockchain in public transportation.

Applications	Disdvantages	Authors
Energy	Utilization of PoW needs a quantity of energy	[25]
Scalability	More scalable systems are needed as the number of contracts and transactions increases	[28]
Confidentiality	Maintaining data and user's privacy	[31]
Legislation	Different regulators' frameworks between countries in terms of cryptocurrencies	[26]

As authors, we propose these other relevant challenges of companies of the transportation public:

a) The high initial investment of companies: Enterprises could require initial costs and investments to apply Blockchain.
b) Specialized Blockchain staff: It is necessary to count on personnel specialized in Blockchain for the excellent development of this technology in the company and the sector.
c) Resistance to change of the managers or staff: Certain firms could resist introducing new technologies, especially when they do not have the appropriate knowledge, skills, and information for the users.

5 Implementation of Smart Contracts in Public Transportation

Based on the advantages and challenges of the application of Blockchain in the transportation sector, some instances of the implementation of Smart Contracts in public transportation could be:

A. Creating a Smart Contract to record the user's ticket. Each company should be informed about the different platforms used to generate smart contracts, such as Ethereum, Hyperledger, etc. The development of smart contracts enables the enhancement of user registration in a decentralized manner and increases data privacy. Providers or firms should maintain the confidentiality of the consumers. This reduces the risk of fraud and illegal behaviors like identity supplantation and the reduction of intermediaries causing a decrease in ticket prices.

B. Permitting payments with cryptocurrencies: Travelers should pay with different cryptocurrencies, guaranteeing the security of the payments, and companies should ensure the scalability of the transactions, improving efficiency and safety and reducing costs.
C. Using a Dapp: The use of Dapps permits the provision of better service to the user, enabling the buying of the ticket and the payment with cryptocurrencies. Enterprises should consider each country's regulations concerning permitting these types of transactions. Dapps facilitates the generation of loyalty programs offering discounts for the most significant utilization of transportation services.
D. Implementing Dynamic Pricing Mechanisms: Smart Contracts enable the implementation of dynamic pricing mechanisms based on real-time data such as demand, traffic conditions, and environmental factors. By automatically adjusting ticket prices according to these variables, transportation providers can optimize resource allocation, alleviate congestion, and incentivize off-peak travel. This dynamic pricing model encourages more efficient use of transportation infrastructure while enhancing the overall user experience.
E. Implementing Carbon Credits and Environmental Incentives: Smart Contracts can be utilized to implement carbon credits and environmental incentives within public transportation systems. By rewarding passengers for choosing sustainable travel options such as walking, cycling, or using public transit, Smart Contracts incentivize eco-friendly behavior and contribute to reducing carbon emissions. Additionally, Blockchain technology enables transparent tracking and verification of carbon credits, enhancing accountability and trust in environmental initiatives.
F. Supporting Decentralized Autonomous Organizations (DAOs) for Governance: Smart Contracts can support the creation of Decentralized Autonomous Organizations (DAOs) for the governance of public transportation systems. Through DAOs, stakeholders such as commuters, operators, and local authorities can collaboratively make decisions regarding service provision, infrastructure investment, and fare policies. This decentralized governance model fosters community participation, fosters innovation, and ensures that the needs of all stakeholders are taken into account.
G. Enabling Transparent and Immutable Feedback Mechanisms: Smart Contracts can be leveraged to create transparent and immutable feedback mechanisms within the public transportation ecosystem. By recording feedback and ratings on the Blockchain, passengers can provide valuable insights into service quality, safety, and reliability. This feedback can then be used by transportation providers to continuously improve their offerings and build trust with passengers. Moreover, the immutable nature of Blockchain ensures that feedback cannot be tampered with, enhancing accountability and transparency within the industry.
H. Facilitating Seamless Intermodal Connectivity: Smart Contracts can facilitate seamless intermodal connectivity by enabling the transfer of ticketing information between different modes of transportation. For instance, a commuter using a combination of bus, train, and bike-sharing services can have their entire journey seamlessly coordinated and paid for through a single Smart Contract. This integration promotes multimodal transportation solutions, reducing reliance on private vehicles and promoting sustainable urban mobility.

I. Integration with Mobility as a Service (MaaS) platforms: Smart Contracts can be seamlessly integrated into MaaS platforms, allowing for the creation of comprehensive mobility solutions. By utilizing Blockchain technology, MaaS providers can streamline the entire transportation experience, from planning routes to purchasing tickets across various modes of transport. This integration fosters interoperability and convenience for users while promoting sustainable travel choices.

The process begins with the user's utilization of the Dapp. Secondly, the user realizes the payment of the price of the ticket. Lastly, the store of the Smart Contract on the Blockchain is completed. The enterprise receives the quantity paid by the traveler, which could be used for the means of transport chosen.

6 Current Works

This section briefly discusses the current works:

a) Combining Blockchain with other technologies: Previous work like [26] combined AI with Blockchain by using a robot in the United States that realizes predictions to match users and drivers who want to share a trip. [32] developed a system integrating ML to predict cyber-attacks and Blockchain, eliminating falsifications of confidential data. Through a distributed ML called Federating Learning (FL), it is possible to update and expect traffic flows [33]. Other previous studies, such as [34], focused on integrating with Digital Twin (DT) to ensure confidentiality and efficiency. [35] and [36] combined the Blockchain into the Metaverse to improve urban transportation/mobility services.
b) Identity management: Other studies, such as [10], proposed a decentralized identity management system to integrate the same travel card in Europe, eliminating the necessity to have one travel card for each transportation provider of the country.
c) Improving the confidentiality, speed, scalability, and Sustainability of public transportation: In previous research, [30] developed a decentralized ride-sharing system integrating a DApp, enabling the user's access to solve issues like confidentiality, high energy, speed, and scalability. This system permits the provision of the data out of the Blockchain, converting them into smaller hashes and automating the process by Smart Contracts.
d) Enhancing security and efficiency of the systems: Applying Blockchain for Internet of Vehicles (IoV) in a 5G context improves the safety and efficiency of the structures [37, 44]. Blockchain reduces costs and improves the efficiency of fleet management and electric bus (EB) charging [38]. Blockchain could improve the security of vehicles (e.g., aircraft) [29].
e) Reducing congestion and pollution: Implementing Blockchain in developing countries could decrease congestion and pollution caused by public transportation [39]. Introducing Blockchain in the carbon trading system reduces the carbon footprint in the public transport industry [40].
f) New payment models: [41] developed a system enabling cryptocurrency payments.
g) Empirical studies: [42] conducted empirical studies to determine opinions about autonomous taxis..

7 Future Research Work

Future research lines could include the development of Blockchain and AI in other regions like the European Union, considering the regulatory framework of all the countries realizing predictions of the use of transport and permitting payments with cryptocurrencies. Developing decentralized identity management throughout the European Union would cause issues at the regulatory level or lack of agreements, so it proposes developing this system between two or three nearby countries to make the contracts more manageable. Conducting empirical studies through surveys to see the users' opinions could be a promissing.

8 Conclusions

Due to the rapid increase in traffic congestion and the concern of sustainability development, it is necessary to know the advantages and challenges of Blockchain for the correct application of this technology in public transportation. Implementing Blockchain applications like cryptocurrencies, Smart Contracts, and Dapps reduces costs, eliminates intermediaries, and increases data safety and transparency, generating more trust and loyalty programs for the users. However, knowing how to apply Blockchain efficiently and sustainably using PoS is necessary, considering the scalability, confidentiality, network speed, and each country's legislation. Moreover, companies and providers must have the required information and the high initial economic and human investment. Providers and public transportation firms should form Smart Contracts to record the user's ticket, enabling payments with cryptocurrencies and creating Dapps for a better service to the consumer. Although current works are focused on integrating Blockchain with applications such as cryptocurrencies and other emergent technologies like AI to improve issues like identity management, confidentiality, scalability, speed, energy, and security efficiency of the systems and to solve the congestion and pollution, it could be interesting to develop more research and empirical studies about the application of Blockchain on Public Transportation. To our knowledge, our paper is the first SLR on the topic, increasing literature knowledge. It contains practical implications providing valuable information to governments, providers, firms, and public transportation users about the functions of Blockchain.

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Active Learning Strategies in the Context of Society 5.0

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Abstract. This study analyzes the integration of active learning strategies into the educational paradigms of Society 5.0, highlighting the role of technological evolution in the student-centered learning process, which promotes critical thinking, problem-solving, and teamwork skills. By analyzing various active learning methodologies and their compatibility with the digital tools and platforms inherent in Society 5.0, we aim to provide some suggestions on how educational systems can evolve to meet the demands of a rapidly changing world. The document argues that the use of technology in active learning contexts improves educational outcomes, as well as empowers students to actively contribute in an increasingly digital, interconnected, and complex society.

Keywords: Active Learning Strategies · Society 5.0 · Technological Evolution

1 Introduction

Society 5.0 represents a vision of a new societal model that reconciles advanced technology with human needs, intending to integrate digital environments and real-life activities. In the context of education, this aggregation presents an opportunity to reinvent and adjust teaching and learning processes. Active learning strategies, which involve students in the learning process through various activities and reflection, stand to gain significantly from the technological advances associated with the characteristics of Society 5.0.

One of the goals of Society 5.0 is to put human beings at the center of technological innovation, particularly to improve quality of life, social responsibility, and sustainability [1]. Consequently, in the pedagogical context, the innovative perspective of Society 5.0 can be related to some of the Sustainable Development Goals (SDGs), such as SDG 4: Quality Education - to ensure access to inclusive, quality, and equitable education and promote lifelong learning opportunities for all, helping students acquire the knowledge and skills needed to promote sustainable development and the SDG 8: Decent work and economic growth – to promote inclusive and sustainable economic growth, full and productive employment and decent work for all, to achieve higher levels of economic productivity through diversification, technological modernization and innovation.

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In this context, this study aims to analyze how active learning strategies can be effectively implemented in the digital age, promoting a dynamic, interactive, and personalized educational environment.

2 Literature Review

2.1 Society 5.0 and Education

The development of technology in recent years has led to major changes in people's attitudes, which must be continuous to prevent society to regress or stay unchanged. Society 5.0 represents a community adept at addressing numerous issues and societal dilemmas by leveraging diverse innovations born in the fourth industrial revolution, including technologies like the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, and robotics [2]. According to [3], Society 5.0 responds to social needs through advanced technology products, such as augmented reality and AI, so this reality cannot be dissociated from the effect of AI in the teaching process.

In this context, Society 5.0 and Education 5.0 aim to develop an environment that enjoys the advantages associated with technological development, while at the same time looking after the well-being and development of individuals. According to [4], Society 5.0 aims to benefit from the potential of the relationship between individuals and technology, increasing people's levels of well-being, happiness, and quality of life, as well as the sustainability of society, through a super-intelligent society.

Education will necessarily have to be a catalyst for this transformation process, which requires a change in the skills of all the people involved in education [5]. [1] argue that universities play a crucial role in the production of knowledge for new technologies and social innovation, since digitalization opens up new perspectives for universities, making it one of the main drivers of change and plays a crucial role in the innovation process.

According to [6], the areas of digital competence encompasses five major areas of competence: information and data literacy, the creation of digital content, communication and collaboration, security in digital environments, and problem-solving, so teachers must be able to acquire skills in these areas of knowledge.

[4] and [7] argue that it is needed greater interdisciplinarity in higher education, particularly in HEIs, through the adoption of innovative learning strategies, curricular flexibility, and the development of students' soft skills, as these are valued by the job market.

[8] reinforce the need to allow students to use their creativity, particularly with the use of technology and the Internet. To this end, students must play a central, active, and autonomous role, with teachers playing a mediating and facilitating role. [9] argue that the continuous use of technology in the learning process promotes active student participation and sustainable education. In addition, the teacher should contribute to the development of morals and ethics through the student-oriented process [1].

Concerning the skills that students should develop, [1] list the following: digital skills, cognitive and metacognitive skills (critical thinking, creative thinking, self-regulation), social and emotional skills (empathy, cooperation), practical skills (use of new tools and

communication technologies), as well as awareness of adopting sustainable solutions. [8] consider the skills associated with data, human, and technological literacy to be fundamental in Education 5.0.

According to [10], the skills that must be developed by the millennial generation, to adapt to the digital Society 5.0 are the following ones: complex problem solving; critical thinking; creativity; people management; coordinating with others; emotional intelligence; judgment and decision making; service orientation; negotiation and cognitive flexibility.

2.2 Active Learning Methodologies

Given the evolution of the environment, in general terms, and of technology, in more specific terms, today's students are characterized as a very different "persona" from the one identified in past decades, and it is necessary to focus on developing students' critical capacity, their ability to reflect on practices developed and their ability to interact with peers and teachers, which goes far beyond traditional, passive learning, where students are passive listeners. This requires, among other things, a frequent need to provide and receive feedback on the development of the work, so that the student is fully aware of their learning process, as well as continuous training on the part of the teachers.

The concept of active learning strategies was pioneered by [11], according to whom students should be involved in an environment conducive to the development of their learning, participating actively in lessons. More than 30 years later, there is still no commonly accepted definition of active learning [12]. However, one of the most consensual characterizations of passive learning is due to [13], according to whom students are involved in the learning process through activities and discussion in the classroom, rather than passively listening to the teacher, emphasizing higher-order thinking by involving the student actively and enthusiastically, understanding the relevance of the teaching-learning process.

[1] recommend that higher education institutions (HEIs) implement active learning programs, as well as the use of technology and digital resources in the teaching and learning process. According to the authors, HEIs are responsible for developing curricula that offer students the opportunity to test their learning and acquire new skills through projects geared toward the needs of organizations, which makes it easier to achieve SDG8, namely in what concerns higher productivity, diversification, and innovation.

Previous studies [7, 12, 14–19] emphasize the benefits associated with the active learning methodologies, which are summarized in Table 1.

These benefits help the new generations, as well as the generations that are moving towards lifelong learning, playing a crucial role in promoting the SDG, in addition to SDG 4 and SDG 8, as can be seen in Fig. 1.

Table 1. Benefits of active learning methodologies - Examples

Examples of benefits of active learning methodologies		
Improvement of critical thinking skills	Increases the student's overconfidence	Increase in the level of students' self-confidence
Students engage with more practices, and discussions are made friendlier	Promotes the construction of new meanings and solutions	More collaboration among students
Stimulates the students to reflect and provide feedback on their peers, discuss and collaborate among themselves	Students construct easily new and deeper understanding of the experience they learn	Improves personal and professional awareness and growth from learning through experiences
Create a positive learning environment	Enhance communication skills	Greater retention of information
Enhance the critical argumentation	Higher student engagement	Enhance the critical thinking

Fig. 1. Sustainable Development Goals.

3 Active Learning Strategies for Society 5.0

Several active learning strategies aim, in particular, to promote the development of students' critical thinking and autonomy, which are adequate for the Society 5.0 era. Among the various strategies, we highlight some of them, as shown in Fig. 2.

Fig. 2. Active Learning Strategies.

3.1 Team-Based Learning (TBL)

It is a collaborative teaching strategy that provides students with the opportunity to apply conceptual knowledge through a sequence of activities, including individual preparation, teamwork, and application exercises, and is recommended for small groups [20]. The four key elements of the TBL strategy are: i) adequately trained teachers; ii) frequent and timely feedback; iii) problem-solving; and iv) peer evaluation.

3.2 Problem-Based Learning (ProBL)

This teaching strategy promotes active learning centered on the students, confronting them with real-world problems, leading them to reflect and attribute meaning to their learning as they find answers to the problems presented to them. In this way, students develop skills such as critical thinking, collaboration, creativity, and communication [21]. The problem must be carefully selected to meet the learning objectives of the course in question. This section discusses the use of virtual and augmented reality to create immersive problem-solving experiences, allowing students to tackle real-world challenges in a controlled, interactive setting.

3.3 Project-Based Learning (PBL)

This methodology allows students to act actively and collaboratively in search of a solution. The students are given a challenge (project) by the teachers, putting different contents into practice and developing knowledge in an active, collaborative, and inter-disciplinary way [22]. The teacher's role is essentially that of facilitator or mentor during the process, which can be relatively long.

3.4 Game-Based Learning (GBL)

GBL enables learning playfully, as it brings the strategies, rules, and social experiences of playing a game into the classroom. This learning methodology allows teachers to target certain activities that will benefit the application of concepts in the real world, generating more immersive and collaborative learning opportunities. Some benefits of GBL are based on improved academic performance, greater motivation and interest in learning, as well as greater retention of acquired knowledge [23]. Among the different GBL techniques, Escape Room games are based on carrying out tasks (puzzles, for example) to achieve a specific goal in a limited time. According to several studies [e.g., 19], this methodology improves communication skills, helps develop problem-solving skills, increases productivity, and strengthens the relationship between the different players.

3.5 Case Studies

The methodology associated with case studies is based on a real narrative, fictional or adapted from reality, as an object of study in the classroom, with the aim of the student putting into practice the knowledge acquired in the meantime on a given topic [24]. For the learning process to be effective, the subject of the work must be properly related to the knowledge previously acquired by the student [25].

3.6 Adaptive Learning Technologies

This learning technology examines how AI and machine learning can tailor educational content to fit the needs and learning pace of individual students, promoting a more personalized learning experience.

AI has only recently blossomed, but its evolution has grown exponentially. In this context, society's learning needs are changing at a very fast pace that we can hardly keep up with. The current digital revolution requires the development of social and emotional skills, along with skills associated with the demands imposed by AI, such as creativity, communication, empathy, critical thinking, problem-solving, and not forgetting ethics, which can be challenged by the challenges that arise from this. More than ever, we need to be aware of the importance of lifelong learning (SDG4), encouraging the acquisition of new skills. According to [26], digital transformation and AI require a redefinition of the skills needed for learning and human development, while recognizing the lack of knowledge in the field of AI, which is one of today's major challenges.

The impact of AI tools should not be focused on competition between machines and human beings, but on cooperation between the two, recognizing the advantages and limitations of AI, and adding the human differential, particularly in terms of creativity and the emotional characteristics of human beings, such as communication and interpersonal relationships. This is the only way to achieve the long-term benefits of AI. Concerning teaching and learning techniques, AI offers a cutting-edge approach to increasing student engagement at all educational levels. Through interactive learning methods, AI can change the way teaching is done, enable almost instant feedback on learning levels, and more effectively assess student engagement in course units. [27] argue that GBLs allow,

on the one hand, the development of games using AI, and on the other hand, they allow games to be used to teach and learn AI itself.

Summarizing, in our point of view, the main contributions of Active Learning Strategies for both academia and society are the enhancing of students' engagement, the improving of learning outcomes, the stimulation of critical thinking communication skills, as well as the motivation for an incessant curiosity and willingness to learn, which reinforces SDG4.

4 Implementation Challenges

Although the benefits of Education in the Society 5.0 era, there are also some barriers to integrating active learning strategies within Society 5.0's educational framework, including technological access disparities, teacher training requirements, and the need for curriculum redesign. According to [28], the main obstacles teachers encounter in the era of Society 5.0 include technological tools, educational approaches, and personnel resources. To face these challenges effectively, educators need to enhance their skills in integrating digital technologies into their teaching practices. However, associated with technological integration, the financial constraints and requirements related to the investments in technology infrastructures and training are often significant obstacles to this development [29, 30].

It is possible to try to advance with potential solutions, such as policy reforms and investment in educational technology, from the policymakers, and professional development programs for educators, so that teachers and facilitators can be no longer classified as "incapable" of teaching in higher schools [18].

However, it should be noted that recently, despite regular requests for increased student-active learning, research indicates that instruction remains mostly traditional and teacher-centered [31, 32]. While research is recognized as a constantly evolving, border-crossing, investigative, and innovative collaborative activity that requires an infrastructure to succeed, the need for collaborative development and supporting infrastructure is rarely mentioned in academic teaching, which is frequently described as individualistic and traditional in research. [31] highlighted the following requirements for student active learning to succeed: (1) improved alignment between research and teaching methods, (2) a supportive infrastructure for research and teaching, and (3) staff professional development and learning.

An important field of AI technologies application is in the financial sector, that HEIs in finance and management should account for in the process of learning and teaching [33]. The financial sector will integrate AI-based transaction channels with existing systems to improve client experience and efficiency. This connection will streamline and improve transaction processes, making them more responsive to consumer needs, associated with the SDG8. One of the current needs concerns green finance issues with consumers becoming more aware of climate change and energy transition needs (SDG7) [34]. The typical change in client interactions is projected to result in a considerable revolution in the financial sector [35].

The transformative potential of Big Data and AI in the financial sector extends beyond operational improvements; these technologies will open up new opportunities

for growth and development, providing financial institutions with a modest advantage in operational efficiency and innovative product and service offerings [36]. It forecasts further revolution, a wider range of business uses, and seamless AI integration with existing systems. These technologies will influence the financial landscape of the future, creating new opportunities for both industry participants and consumers. For that, a hard path is still there to be followed in terms of educational needs and adaptation [37, 38].

In accounting, [39] provide a systematic literature review, noticing an urgent and pressing need for educational institutions, their audiences, and other entities to interact in the changing process. Thus, it was advised to foster synergies to ensure the success of retraining this valuable strategic resource in organizations and society, as well as the profession's sustainability, promoting a sustainable Society 5.0. But, in finance and management education fields we find little or even inexistent assessment of students' needs in HEIs and the necessary adaptations for Society 5.0. Transition challenges for education in the transition for Society 5.0 are also identified by [40].

[41] findings indicate that faculty members' perspectives on the performance of teacher education programs in creating lifelong learning capacity are varied (SDG4). Some faculty members assume these programs are effective, while others believe there is still space for improvement. Those who believe, frequently cite the utilization of hands-on, practical experiences, the inclusion of technology, and chances for professional growth as significant factors in students' success. Thus, faculty members' perspectives on the effectiveness of teacher education programs in creating lifetime learning competency are diverse and nuanced.

For the moment, the present study sheds light on critical factors that HEIs, should resolve in different learning areas, and adopt to support future needs. Among these, we would highlight decision-making strategies, operational policies and governance, financial investments, and policymaking, at a time when "digital technologies" have become an unavoidable and indispensable part of education and learning.

5 Conclusions

This research examines how active learning approaches are incorporated within the educational frameworks of Society 5.0. It emphasizes the significance of technological advancement in the learner-driven educational journey, fostering abilities in critical thinking, problem-solving, and collaboration.

We focus on Society 5.0 and Education, on the active Learning methodologies benefits, and give some examples of active learning strategies, as well as their association with the digital tools and platforms inherent in the Society 5.0 era, reflecting also on the main implementation challenges.

The conclusion underscores the necessity of active learning methods in readying students for the intricate demands of Society 5.0. It advocates for continuous exploration into efficient teaching strategies that utilize technology to improve educational outcomes and proposes potential topics for further study, including the enduring effects of these approaches on student achievement in a technologically advanced environment.

In a deeper analysis, the authors would like to reinforce the contributions of the study, offering insightful approaches to tackle the main challenges pointed out so far.

Future works on this topic should focus on specific trends, such as AI, Big Data, Cyber Security, Ethics, and their impacts on sustainable Education 5.0.

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Artificial Intelligence System for Digitization of Traditional Folk Music Performances

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Abstract. Nowadays, in the field of digital humanities and ethnomusicology, the preservation and analysis of traditional European folk music presents unique challenges and opportunities. This paper introduces an innovative Artificial Intelligence (AI) system designed to address these challenges by digitizing performances of traditional European folk music. Employing artificial intelligence techniques, the system processes pre-recorded video performances to extract crucial musical information, including the transcription of audio into musical scores and, where applicable, the transcription of lyrics. The core functionality of this system leverages state-of-the-art techniques in machine learning in the area of audio processing, enabling the interpretation and transcription of complex musical compositions and vocal performances. The aim of this research is to contribute significantly to the preservation and accessibility of traditional folk music, highlighting the potential of AI in ethnomusicology and digital humanities. This paper details the proposed system's architecture, methodologies for audio and video processing, and the challenges encountered in capturing the nuances of traditional folk music. Preliminary results of the system on a digital archive of traditional music from Portugal are presented, and the effectiveness and drawbacks of the system in producing detailed and accurate musical and lyric transcriptions are discussed. The tool is publicly available for musicians, scholars, and enthusiasts of traditional European folk music.

Keywords: Folk Music Digitization · Audio Transcription · Music Score Generation · Lyrics Transcription · Artificial Intelligence

1 Introduction

The preservation of cultural heritage, especially traditional music, is a pressing issue in our increasingly digital world. Traditional music, an integral part of cultural identity, faces a unique set of challenges due to its primary mode of transmission: oral tradition. This ancient practice, while culturally enriching and historically significant, presents significant barriers to preservation and documentation. Oral transmission, by its very nature, lacks the permanence and consistency of written or recorded formats and requires meticulous transcription efforts to ensure its survival for future generations.

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In addition, the urgent need for digitalization is underlined by the vast collections of documents related to traditional music held by archives and cultural associations. Part of these collections, which are often large and diverse, remain largely inaccessible to the general public and scholars due to their non-digital formats. Digitizing these materials is essential not only for their preservation, but also for the dissemination of cultural roots that might otherwise be lost to time.

Digitizing these pieces of music requires a number of specialized tasks. These include transcribing handwritten scores into digital formats, extracting scores from audio recordings, recognizing and transcribing lyrics, and adding useful metadata for later retrieval and analysis. Such metadata can include musical characteristics such as key, mode and genre, which are essential for understanding the piece in its specific cultural context. These tasks are carried out manually by experts in the field and are time-consuming. While challenging, these tasks are critical to the effective preservation and accessibility of traditional music. By digitizing these materials, we are not only safeguarding cultural heritage, but also opening up new avenues for research, education and appreciation of the rich tapestry of human musical expression.

In addressing the multifaceted challenges of traditional music digitalization, the development of automated tools becomes not just beneficial, but essential. The intricate nature of tasks calls for solutions that go beyond manual efforts. Here, the integration of modern data science and artificial intelligence (AI) into the digitalization process emerges as a critical requirement. These advanced technologies have the potential to significantly streamline, and in many instances, fully automate various aspects of the digitalization process, thereby enhancing efficiency and accuracy.

This work presents a disruptive tool designed to address these challenges. The main contribution of this work is the development of an artificial intelligence-driven tool for the digitization of video performances of traditional music. A notable feature of this tool is its ability to automatically generate lyrics and an approximate transcription of the main melody from video recordings. This tool can be used in the digitization process carried out in archives and also in the automatic enrichment of digital content already offered on the internet by cultural associations. This innovation combines and applies cutting-edge available work in artificial intelligence to the field of digital humanities, offering a novel approach to the preservation and accessibility of traditional music.

2 Background

2.1 Digitalization of Folk Music

The digitization of folk music involves a wide range of tasks, each of which is essential to preserving the rich cultural heritage inherent in these musical traditions. As we explore this area, it is crucial to understand and define the key tasks that could be automated to improve the efficiency and accuracy of the process.

Firstly, a fundamental task is the transcription of handwritten scores into digital formats such as ABC notation [1], MusicXML [2] or MEI [3], this task is called Optical Music Recognition (OMR) [4]. This process not only preserves the original composition but also facilitates wider accessibility and analysis. However, this transcription is often

complex, requiring a deep understanding of music notation and the nuances of historical and cultural contexts.

Secondly, transcribing raw audio into sheet music [5] is a complex challenge, especially in cases where multiple instruments and voices are involved. This task requires sophisticated audio processing techniques to accurately capture and represent the various elements of the composition.

Moreover, transcribing lyrics from audio recordings is another critical task [6], requiring prior recognition of the language for accurate transcription. This step is essential for understanding the cultural and emotional context of the music.

In addition, identifying the genre [7] or sub-genre within a musical culture is essential for categorizing and understanding the music in its cultural context. This involves analyzing musical elements and patterns that are characteristic of particular genres or sub-genres.

Furthermore, identifying the key and mode of music [8] is crucial for musicological analysis, providing insights into the structural and emotional aspects of the piece.

Additionally, the automated detection and tagging of musical instruments [9] or other kinds of labels within recordings can greatly enhance the metadata associated with a piece, making it easier to classify and retrieve.

Lastly, the extraction of musical patterns [10] is pivotal for discovering similarities with other pieces in the same repository. This not only aids in the classification and study of music but also in uncovering the interconnectedness of various musical traditions.

In this work we focus the development of the tool on two of these tasks that are detailed in the following sections.

2.2 Transcription of Lyrics from Raw Audio

Automatic lyrics transcription (ALT) [6, 11] is the process of estimating sung lyrics from musical recordings, often in the presence of instrumental accompaniment.

With the rise of music creation and sharing by non-professionals, for example on video sharing sites such as YouTube, there has been a rapid increase in unannotated music data without lyric transcriptions. In the field of this work, traditional music, it is common to find recordings without lyrics. The task of transcribing the lyrics of these songs manually is a difficult and sometimes time-consuming task. This has made ALT increasingly important in the music information retrieval community for its applications in karaoke lyric generation and text-based indexing. Many ALT studies have adapted Automatic Speech Recognition (ASR) techniques, with modifications where necessary, due to the similarities between the goals of ALT and ASR. The aim of lyric transcription is to identify the words of sung utterances, in the same way as in automatic speech recognition.

One of the most commonly used evaluation metrics has been the Word Error Rate (WER), but there are already recent works [12] that propose metrics more focused on lyrics instead of those commonly used in ASR such as WER.

In this study, we will use the most advanced open model available in the field, to the best of our knowledge, and highlighted in some benchmarks [12, 13], for the development of the proposed tool. Specifically, we have chosen to use the Whisper v3 [14] model developed by OpenAI, which represents the current state of the art in the

field. In addition, to improve the quality of the detection we include a previous step of source separation that is used in many works, using a state-of-the-art library in source separation, the Deezer's Spleeter library [15]. This library will be used in the work to separate the vocal part from the accompaniment in order to get a better transcription of the lyrics of the song. A schema of an approach of the automatic lyrics transcription process is shown in Fig. 1.

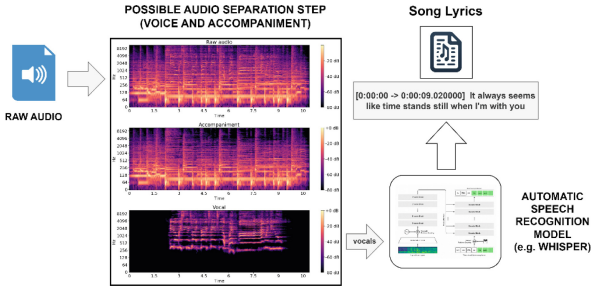

Fig. 1. Automatic Music Transcription Task.

2.3 Transcription of Audio to Sheet Scores from Raw Audio

One task within the field of Music Information retrieval (MIR) is known as Automatic Music Transcription (AMT) [5, 16]. The final goal of this task is to extract a symbolic representation that a human can interpret and understand (e.g. a music score) from an audio signal.

To derive a modern score from an audio signal, it's essential to identify notes (pitch and duration), silence (duration), and interpretive symbols such as key signatures, meter, and clefs. Beyond these basics, a score communicates the composer's performance instructions through various symbols (e.g. slurs, crescendos) whose meanings can change over time. The output of any AMT system is therefore only an approximation of the original score used in performance. The scientific literature identifies four levels of automatic music transcription [5]: (1) frame-level, (2) note-level, (3) stream-level and (4) notation-level (the task addressed in this work). A diagram of this process is shown in Fig. 1. Music transcription proceeds through a hierarchy of complexity, starting with frame-level transcription, which analyses basic sound elements such as pitch and timbre in short segments of audio. This is followed by note-level transcription, which connects these pitches over time to form distinct musical notes, focusing on their pitch, onset and duration. Stream-level transcription then groups these notes into coherent streams, typically representing different instruments or voices, and emphasizes longer, discontinuous pitch patterns and timbral characteristics. As music transcription progresses from frame level to note level and then to stream level, the task becomes increasingly complex, requiring the modelling of more detailed musical structures and cues. The outputs at these levels are parametric transcriptions of audio content, exemplified by the MIDI piano roll representation. However, these transcriptions are still not as abstract as music notation, lacking elements like beats, bars, meter, key, harmony, and stream, and using seconds and MIDI numbers instead of spelled note names and rhythmic notations. The highest

level, notation-level transcription, creates a formal written representation that incorporates individual notes, beats and musical symbols such as dynamics and harmonics. In addition to this, depending on the audio it is possible to differentiate between monophonic and polyphonic musical contexts, the latter presenting the greatest challenge in music transcription research [17]. A diagram of these levels is shown in Fig. 2.

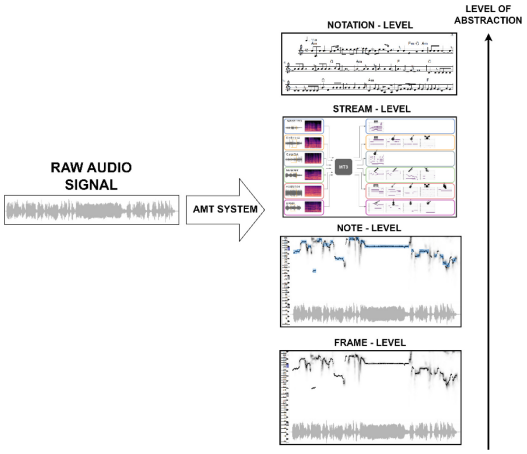

Fig. 2. Levels of Automatic Music Transcription task.

This task (at different levels) has been explored and approached from scientific literature works [16, 18] in the past years and from the market providing tools such as Tony [19], ScoreCloud [20], AnthemScore [21] among others. This type of system has many applications, from the field of education to be able to retrieve scores of songs and teach them to students [22], systems for detecting plagiarism in songs [23], music recommendation systems [24] that use the musical attributes in the recommendation or, as is the scope of this work, its use in music archiving and restoration[25].

In this work we have used one of the latest works in the state of the art in this field, that is, the work developed by Donahue et al. [26] to extract the melody directly from the raw audio. In this work, an evaluation is performed with different approaches and latent representations, one of them being the embeddings obtained with Jukebox [27] embeddings. According to their results, this approach is the one that provides the best results on melody transcription.

3 Proposed System

The main objective of the system proposed in this work is to be able to obtain, from a URL of a multimedia resource (audio or video), the audio of the vocal part of the song, the transcription of the lyrics and an approximation of the general melody of the song in a music score format and in MIDI format. To achieve this objective, the following pipeline has been designed and is shown in Fig. 3.

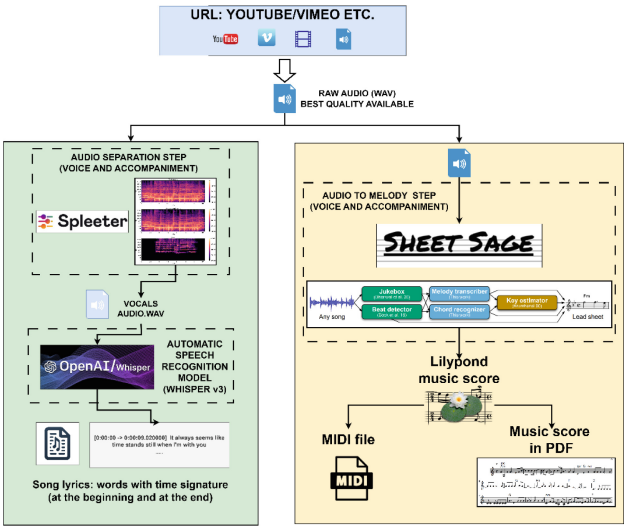

Fig. 3. Pipeline of the proposed system.

The first step is to retrieve the audio from the given URL and convert it to WAV format. Once the audio has been obtained, the next step is to obtain the lyrics of the song. At this stage, the audio is processed by performing a source separation using a Deezer library called Spleeter [28]. This separation divides the original audio into two stems: (1) vocals, with the singer's voice, and (2) accompaniment, with the rest of the music without the singer's voice. This is done using a pre-trained model of the library. After performing the separation, the transcription of the separated audio with the vocals is done with an ASR model, in this case the recent Whisper v3 model with the faster-whisper library[29], which is a re-implementation of OpenAI's Whisper model using CTranslate2 [30], a fast inference engine for Transformer models, that is 4 times faster than the original and shows the same accuracy while using less memory. The model can automatically perform language detection from the first 30 s of audio provided. Otherwise, the target language must be provided as a parameter for it to perform the transcription. The result of this stage is a collection of text segments with time stamps indicating the start and end of each word in the segment. This makes it possible to obtain the entire text, or at any point in time (which can be used for karaoke-type tools).

The next step is to transform the complete raw audio into MIDI score format. For this task we have used the work of Donahue et. al. Called *sheetsage* [31], and we have used the version that uses Jukebox embeddings to perform the process of obtaining the melody, as these are the ones that gave the best results in the original work. The process of using the Jukebox embeddings has a very high computational cost and is quite time-consuming compared to the rest of the system steps, however it can offer better results than not using the embeddings. At the end of this process, a score is obtained, from which a PDF and its transcription in MIDI format are generated, as well as a synthesized sound, so that the result obtained can be easily evaluated at the same time as the score.

4 Case Study

As a case study for the first pilot test of the system, we worked with the Portuguese non-profit association "A Música Portuguesa A Gostar de La Própia" (MPAGDP) [32]. This association has been documenting the oral tradition of traditional Portuguese music for more than ten years, traversing the country from north to south to find people who still sing and use their memory to recall the songs and traditions handed down from generation to generation. This association has done an enormous amount of documentation, recording all kinds of documents: songs, prayers, blessings, dances, music, stories, etc. So much so that on their Vimeo channel [33] they have more than 7000 high quality videos related to traditional Portuguese music.

This huge amount of information would require a lot of time to manually analyse in order to obtain information such as song lyrics and sheet music. For the latter, you also need to have the musical knowledge to transcribe it. The system proposed in this work is motivated by cases like this, where the possibility of obtaining the lyrics of popular songs, and above all an approximation of their partiture, would facilitate their documentation and also their transmission to teach them to future generations. For these reasons, it is proposed as a case study the creation of a web tool that implements the proposed system and also its use to extract the lyrics and the lyrics of songs by simply entering the URL of the association's existing videos. A picture of the developed tool is shown in Fig. 4. Once the URL of the video has been typed into the tool, the tool will load a preview of the video and allow you to start processing it by clicking on the button below. The process will start, and a spinner will be displayed showing the progress and each stage of the process. Finally, the results are displayed below, as shown in Fig. 4. It shows the result of the transcription of the lyrics, the detected language, and the processed score in PDF. This small tool will allow validating the proposed pipeline, correcting possible errors, improving aspects of the processing and adding new functionalities proposed after its use in a first alpha phase.

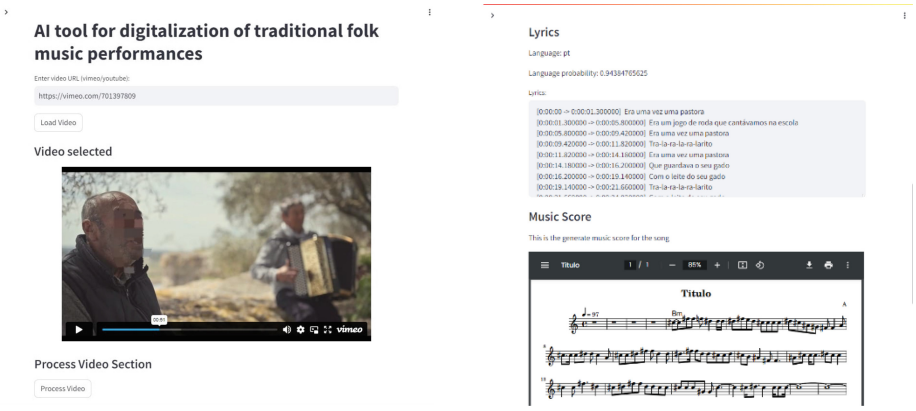

Fig. 4. Main view of the video and results processing tool.

After this case study, the pipeline will be refined in order to be able to expose it as a web service that allows us to provide the outputs to other systems, allowing to make this process automatic over all the existing catalogue of this association and of other institutions such as traditional music archives that want to use it. For the development of the tool, the Streamlit framework [34] for rapid development of a web application has been used. This tool is publicly available[1] [35] for open-source use.

5 Preliminary Results and Discussion

The tool is currently in the alpha testing phase and is being tested by staff of the association MPAGDP and has been shared with the partners of the DIGIFOLK Project [36] in which this work is framed. After the first tests of the tool and the different parts of the system, some results can already be extracted to improve the system and to analyze it further in the future.

On the task of automatic lyrics transcription, there are several issues that need to be addressed. Firstly, the language detection in the model needs to be improved so that it is not limited to only the first 30 s of the audio. Additionally, periods of silence cause models such as Whisper to generate hallucinations and not function correctly, as shown in Fig. 5.

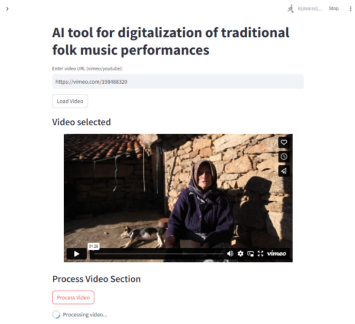

Fig. 5. Example of the tool applied to the video "Era uma vez uma pastora"[37].

In order to evaluate the system in a methodologically correct way and to test this part of the proposed system in a consistent way, it is necessary to use a dataset and carry out measurements with a metric such as WER, which is commonly used in ASR. This dataset could be elaborated with the lyrics of the songs of the videos of these corpora, which are available on other sites such as CantarMais.pt [38] or which the MPAGDP has collected on its website. However, this information is not currently available and will be the next step in this work. There is also the additional problem that the recordings do not only contain the performance but may also contain more conversations with the people who often perform this type of music (e.g. Figure 5), making it more difficult to automatically evaluate the available corpus.

[1] https://github.com/elloza/AI-System-for-Digitalization-of-traditional-folk-music-performance.

Despite these problems, the first tests show promising results in the transcription of the lyrics, using as a reference the videos from which the lyrics were already available, as can be seen in Fig. 6. In this image it is shown how the model has transcribed both the song [37] and the subsequent conversation that the singer has in it. The transcription of the general melody from video to score is the biggest challenge of the system. After the first tests of the system, and consultation with experts with musical knowledge, the complexity of the problem is clear. First of all, as with the other part of the proposed system, there are not all the transcriptions of the songs in score with which to evaluate the system in a systematic way.

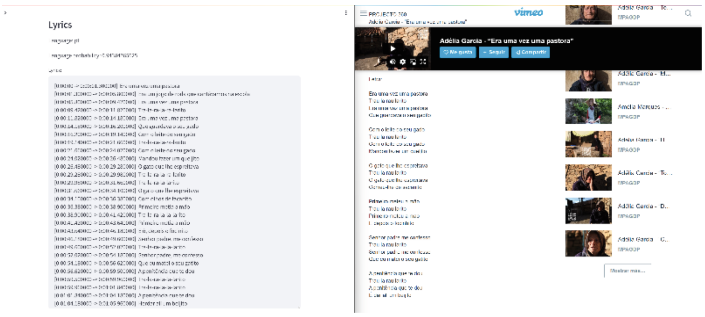

Fig. 6. Results of the automatic lyrics transcription on "Era uma vez uma pastora" [37].

Only scores of some traditional songs are available, found on other websites such as [38], where a certain version of the song can be found. However, this problem is made even more complex by the fact that the version performed by the singer may not correspond to the available score and, moreover, singers of traditional music are often not professional artists who perform a score but rather sing the version they learned orally from acquaintances or relatives. This makes systematic evaluation a hard task. Despite these issues, the tool can be applied to extract the melody, and although the score may not be harmonically correct, the MIDI transcription and its playback are suggestive of the performed version and can be used as a basis for a possible manual transcription. This is shown in Fig. 7.

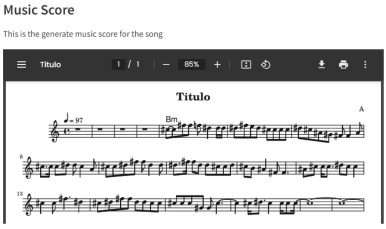

Fig. 7. Results of the automatic melody transcription on "Era uma vez uma pastora" [37].

Therefore, it was suggested to integrate an editor into the generated score tool, so that experts in the field could easily make corrections and save a corrected version of the transcription. Only scores of some traditional songs are available, found on other websites such as [38], where a certain version of the song can be found. However, this problem is made even more complex by the fact that the version performed by the singer may not correspond to the available score and, moreover, singers of traditional music are often not professional artists who perform a score but rather sing the version they learned orally from acquaintances or relatives. This makes systematic evaluation a hard task. Despite these issues, the tool can be applied to extract the melody, and although the score may not be harmonically correct, the MIDI transcription and its playback are suggestive of the performed version and can be used as a basis for a possible manual transcription. This is shown in Fig. 7. Therefore, it was suggested to integrate an editor into the generated score tool, so that experts in the field could easily make corrections and save a corrected version of the transcription.

6 Conclusions and Future Work

In conclusion, this paper presents a tool that can perform advanced music transcription tasks. The system design uses the latest open-source technologies and state-of-the-art models, ensuring both cutting-edge performance and accessibility. The tool is available for use with any type of video, extending its utility beyond traditional boundaries. A major limitation of the tool is its high consumption of GPU resources which requires a powerful computer if consumed locally or offered as a service on a dedicated server.

The tool has been shown to accurately transcribe lyrics from various video sources in initial test results. However, limitations have been identified in the detection of language and the possibility of hallucinations. Regarding the transcription of the song's melody, the system can only provide an approximation due to two limiting factors: the interpretation of the people in the videos and the lack of a ground through reference, which makes this a really difficult task and one that requires further research. As for the proposed lines of improvement, firstly a quantitative evaluation of the ALT subsystem in a specific domain such as traditional music is proposed with the elaboration of a dataset for it. Secondly, the evaluation for scores is presented as a future but potentially very costly work. Regarding improvements to the application, several proposals have been received from the users of the tool to add elements that allow editing the final lyrics and the generated melody, correcting possible bugs and errors.

Finally, although the tool shows potential in music transcription, its current limitations and identified areas for improvement emphasize the need for ongoing development, research, and refinement. The next steps will focus on addressing these challenges and enhancing the tool's capabilities for more reliable and comprehensive music transcription.

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Agent-Based Model for Predicting the Impact of Generative AI

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Abstract. Generative artificial intelligence (AI) systems have revolutionized various industries by autonomously generating content, mimicking human creativity. However, concerns about their social and economic consequences arise with widespread adoption. This paper explores these consequences using agent-based modeling (ABM), aiming to predict the impact of generative AI on societal frameworks. The ABM incorporates individual, business, and government agents, simulating education, skills acquisition, AI adoption, and regulation dynamics. Leveraging ABM, this study contributes to understanding AI's complex interactions, offering insights for policy-making processes. The literature review highlights ABM's efficacy in forecasting AI impacts. Results indicate AI adoption, employment, and regulation trends, suggesting potential policy implications. Future work involves refining the model, assessing long-term implications and ethical considerations, and advancing understanding of generative AI's societal effects.

Keywords: agent-based model · prediction · Artificial Intelligence · generative AI · social and economic prediction

1 Introduction

Generative artificial intelligence (AI) systems have gained significant traction in recent years [21], revolutionizing various industries such as healthcare, finance, and entertainment. These systems can autonomously generate content, including text, images, audio, and video, mimicking human-like creativity. While generative AI holds immense promise in enhancing [22] productivity and innovation, its widespread adoption raises concerns about its potential social and economic consequences. Therefore, there is a pressing need to understand and predict the implications of generative AI within societal frameworks.

In this paper, we aim to explore the social and economic consequences of using generative AI through the lens of agent-based modeling (ABM). Our objectives include proposing a possible agent-based model to simulate the impact of generative AI adoption and its interactions within socio-economic systems. Specifically, we seek to:

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- Conduct a comprehensive literature review to identify existing research on generative AI's social and economic implications.
- Propose an agent-based model that captures the complex dynamics of generative AI adoption and its effects on various societal factors.
- Implement the proposed model and validate its efficacy in predicting the social and economic consequences of using generative AI.
- Present the results of our simulations and analyze the potential implications for policy-making and decision-making processes.

Our approach begins with a thorough literature review to gather insights into generative AI's social and economic impacts. Building on existing research, we propose an agent-based model that incorporates key variables and relationships relevant to adopting and utilizing generative AI within society. We then implement the model using appropriate simulation techniques and validate its performance against real-world data where possible. Finally, we present the results of our simulations, highlighting key findings and discussing their implications for stakeholders and policymakers.

Our study aims to contribute to a better understanding of the complex interactions between generative AI and socio-economic systems, providing valuable insights into the potential consequences of its widespread adoption. Through agent-based modeling, we seek to offer a predictive framework for assessing the social and economic implications of using generative AI, thereby informing decision-making processes and facilitating the development of policies that balance innovation with societal well-being.

2 Literature Review

Agent-based modeling (ABM) emerges as a robust methodology for predicting the multifaceted impact of generative artificial Intelligence (AI) on socio-economic systems [1, 2]. This innovative approach facilitates the simulation of micro-level agents whose interactions give rise to macroscopic patterns aligned with predetermined objectives, providing insights into the intricate dynamics inherent in generative AI systems [2, 3]. By reverse-engineering desired outcomes, researchers can unravel the underlying rules and parameters governing these agents, thereby enhancing our understanding of AI's societal implications [2].

Furthermore, ABM holds promise for evaluating the social repercussions of generative AI systems across diverse modalities, including text, images, audio, and video [4, 5]. By specifying fundamental agent-rule components and permissible combinators, ABM enables a nuanced analysis of various dimensions such as biases, stereotypes, representational harms, cultural values, and disparate performance [5]. Additionally, ABM facilitates the assessment of financial costs, environmental impacts, and labor costs associated with data and content moderation, contributing to a comprehensive understanding of AI's socio-economic ramifications [5].

Leveraging insights from ABM empowers researchers to make informed decisions regarding integrating generative AI into societal frameworks [6, 7]. Comprehensive simulations and analyses, supported by empirical evidence, enable stakeholders to anticipate and address complex challenges posed by AI technologies, thereby maximizing societal benefits while mitigating potential negative consequences [6, 7].

In conclusion, ABM is a valuable tool for forecasting and analyzing generative AI systems' social and economic impacts [8]. By simulating complex interactions and dynamics, ABM facilitates a comprehensive understanding of AI's potential societal consequences, informing strategic decision-making and policy development [9].

3 Proposing a Set of Agents

In our agent-based model, we aim to predict the impact of Generative AI adoption on various societal factors such as education, skills, employment, and government regulation. The model incorporates three primary types of agents: individual agents, business agents, and government agents. The dynamics of each agent are described by differential equations representing their continuous-time evolution. This model is based on design science research [19] and follows similar architecture to previous multi agent systems studies [20].

3.1 A. Individual Agents

The dynamics for individual agents involving education and skill acquisition follow logistic growth models and differential equations commonly used in educational and psychological studies [10]. The sigmoid function used for modeling skill acquisition represents the concept of diminishing returns, a principle well-documented in both educational theory and cognitive psychology [11, 12]. Each agent seeks education (E(t)) and acquires skills (S(t)). Education is influenced by the rate of seeking (α), and skills are influenced by education and the learning rate (β). The equations governing individual agents are:

$$dE/dt = \alpha \cdot (1 - E(t)) \tag{1}$$

$$dSdt = \beta \cdot E(t)S(t) = 11 + e - \beta \cdot E(t), normaliz : bw\ 0\ and\ 1$$

Applying a sigmoid function to the skill level as it's updated introduces a non-linear growth pattern. Early on, as education increases, skills will grow quickly. As skills approach the maximum limit (asymptote of the sigmoid function), additional education results in smaller increases in skill, reflecting a more realistic learning curve. Practical Implications:

- It represents a realistic learning curve where initial education leads to significant skill gains, but these gains taper off as one becomes more skilled.
- It models the psychological principle of diminishing returns in learning.
- It can simulate scenarios where individuals continue to learn and develop skills, but the impact of further education is less pronounced as they become more skilled.

3.2 B. Business Agents

Business agents' behavior, particularly their adoption of generative AI based on available skills, can be modeled by logistic growth influenced by internal learning rates, echoing

theories from business management and economics regarding technology adoption [13]. Businesses adopt Generative AI (A(t)) based on the skills possessed by individual agents. The adoption rate is influenced by the learning rate of businesses (γ).

The equation governing business agents is:

$$dA/dt = \gamma \cdot (1 - A(t)) \cdot S(t) \tag{2}$$

3.3 C. Labor Market (Employment):

The integration of skills' probability density functions into labor market dynamics uses statistical methods typical in labor economics, especially for modeling labor supply and demand shifts due to technological change [14]. Let f(S, t) represent the skills' probability density function (PDF) at time t, where S is the skill level. The total supply of labor (Total Supply Labor(t)) is given by the integral of the product of skill level and probability density function:

$$Total\ Supply\ Labor(t) = \int[-\infty, \infty] S \cdot f(S, t) \cdot dS \tag{3}$$

The total demand factor (Total Demand Factor(t)) is influenced by the adoption of Generative AI (A(t)) and other potential factors:

$$Total\ Demand\ Factor(t) = \gamma \cdot (1 - A(t)) \tag{4}$$

The dynamics of employment are governed by the rate of change of the integral representing the minimum of total supply labor, total demand factor, and the maximum supply labor threshold (Max Supply Labor):

$$dEmployment/dt = d/dt[min(\int[-\infty, \infty] S \cdot f(S, t) \cdot dS,\ \gamma \cdot (1 - A(t)),\ Max\ Supply\ Labor)] \tag{5}$$

3.4 D. Government Agent

The modeling of government regulation as a response to AI adoption levels can draw on theories from regulatory economics and public policy, particularly those discussing the feedback mechanisms between industry behavior and regulatory adjustments [15]. The government regulates AI development (R(t)) based on the level of Generative AI adoption. The regulation rate is influenced by a regulation factor (δ). The equation governing the government agent is:

$$dR/dt = \delta \cdot (A(t) - R(t)) \tag{6}$$

3.5 E. Model Dynamics and Predictions

Education and Skills: Individual agents continuously seek education, leading to an increase in skills over time. This reflects the ongoing learning and skill development in the population.

Generative AI Adoption: Businesses adopt Generative AI at a rate influenced by the population's skills. As skills increase, the adoption of AI by businesses is expected to grow.

Employment: Employment is a dynamic variable influenced by both the supply and demand for labor. The model predicts how the adoption of Generative AI impacts the balance between labor supply and demand, affecting overall employment levels.

Government Regulation: The government regulates AI development based on the level of AI adoption. This regulation is a feedback mechanism that aims to control and manage the societal impact of AI.

Differential equations and integrals allow for a continuous-time representation of agent behaviors and their interactions, providing insights into the long-term effects of Generative AI adoption on various societal aspects..

4 Implementation

We have implemented the proposed agent-based model using the Python programming language, leveraging libraries such as NumPy and Matplotlib to facilitate its development. The model architecture revolves around four main classes:

- IndividualAgent: Represents individual agents engaged in seeking education and supplying labor.
- BusinessAgent: Reflects businesses adopting generative AI technology and influencing economic labor demand.
- LaborMarket: Facilitates the matching of labor supply and demand, serving as the dynamic nexus of the labor ecosystem.
- GovernmentAgent: Governs the regulation of AI development based on prevailing AI adoption levels, shaping the technological landscape.

Upon initialization, the model is equipped with parameters such as learning rates, adoption rates, and regulatory factors. We establish initial conditions for education, skills, AI adoption, and regulation before commencing simulation over multiple time steps, enabling observation of its behavior and prediction of outcomes. Figure 1 shows a small agent community simulation.

The simulation outcomes provide invaluable insights into generative AI adoption's potential social and economic ramifications. Notable trends include businesses' escalating adoption of AI as individuals acquire skills, thereby influencing employment levels and government regulation. The model is a versatile tool for exploring diverse scenarios and conducting thorough analyses of parameter impacts on outcomes.

From a software engineering perspective, our code adheres to best practices in design and implementation. Embracing an object-oriented paradigm, we organize functionality into cohesive classes—IndividualAgent, BusinessAgent, LaborMarket, GovernmentAgent, and AgentBasedModel—enhancing readability and modularity. This architectural

approach promotes scalability and maintainability by encapsulating related behavior and attributes within well-defined abstractions.

Each class's constructor methods (init) are central in initializing object attributes and fostering encapsulation and abstraction. This design decision facilitates code reusability and clarity by encapsulating object state and behavior within self-contained units. The simulate method within the AgentBasedModel class encapsulates the simulation logic, ensuring separation of concerns and modularity. This modular structure allows for seamless modification, extension, or replacement of simulation components without disrupting other model facets.

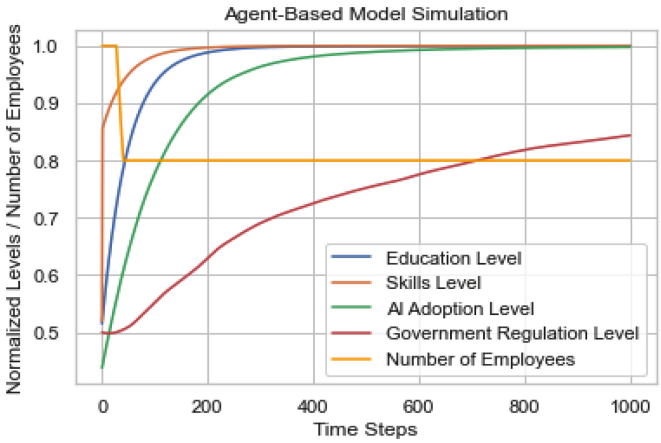

Fig. 1. Small Agent-Based Model Simulation**.**

Moreover, the set_initial_conditions method empowers users to specify initial parameters and conditions, augmenting simulation flexibility and configurability. By decoupling initialization logic from the primary simulation loop, this method facilitates experimentation with diverse scenarios and parameter values, bolstering sensitivity analysis and model validation efforts.

Random variability in alpha, beta, and gamma parameters imbues the simulation with stochasticity, mirroring real-world uncertainties and heterogeneities. This stochastic element enriches the model's realism, enabling the exploration of probabilistic outcomes and scenarios.

Furthermore, error-handling mechanisms are implemented to safeguard against negative values or invalid states in specific attributes, such as demand_factor and regulation. These defensive programming practices fortify simulation stability and correctness, ensuring robustness and reliability in results.

In summary, our agent-based model epitomizes rigorous software engineering principles and design patterns, harnessing the versatility of Python and the robust capabilities of libraries like NumPy and Matplotlib. It offers a flexible, robust, and interpretable framework for in-depth analysis of labor market dynamics, facilitating comprehensive studies at the intersection of economics, education, and technology adoption.

5 Results and Discussion

The model presented may give some insights into education level, skills level, AI adoption, government regulation, and employment level. This is shown in Fig. 2 (next page) where we use a large community (100 k) of agents over 100 simulations and 1k timesteps.

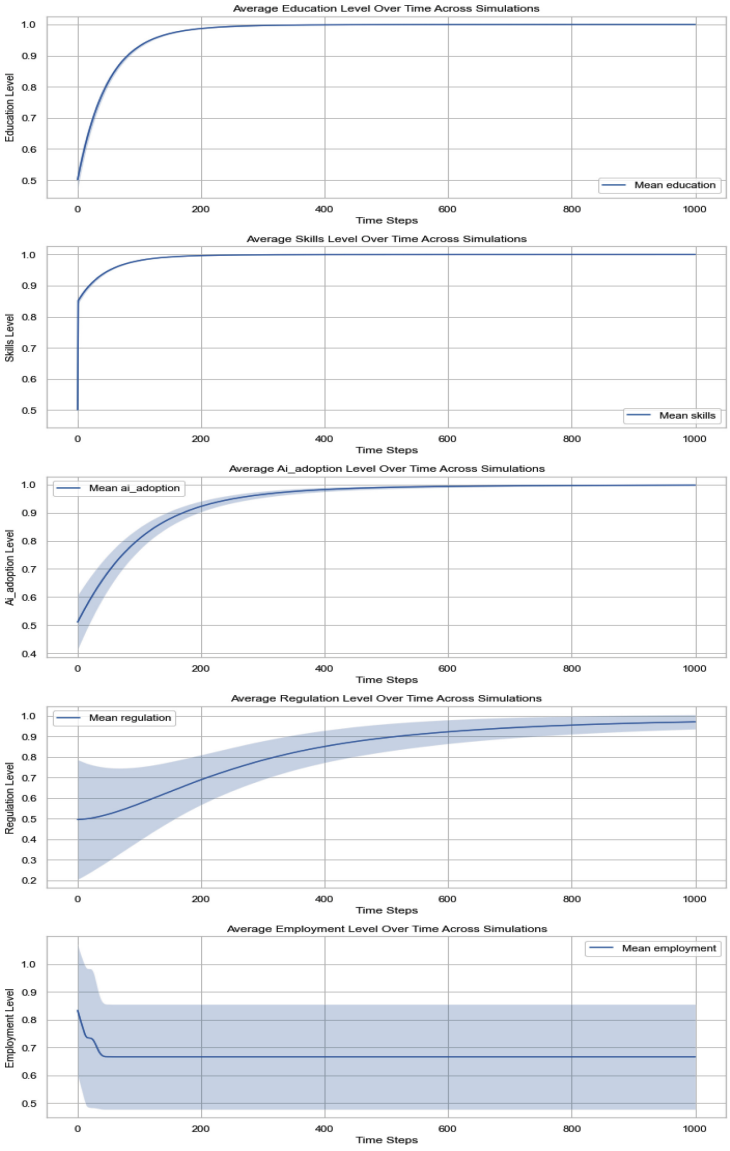

Fig. 2. Agent-Based Model Simulation.

The education level shows a logistic growth pattern, quickly reaching a saturation point. This reflects a scenario where individuals rapidly acquire education until a certain threshold, beyond which additional education does not significantly increase the education level. This could imply diminishing returns to investment in education or that other factors may limit further growth once a certain education level is reached. Which is consistent to current literature [16].

The skills level derived from education using a normalized sigmoid function also follows a logistic growth curve but with a different scale. This shows that as individuals become more educated, their skills increase at a diminishing rate, approaching an upper limit. This could reflect real-life scenarios where, after a certain point, further education results in smaller incremental increases in practical skills.

AI Adoption: The level of AI adoption grows over time, suggesting that businesses continuously adopt more AI technology as they respond to the skills available in the labor market, like in [18]. The availability of skilled labor, government regulations, and the businesses' internal decision-making processes could influence the adoption rate.

The regulation level appears to be increasing steadily. This could be a government's response to the rising adoption of AI, aiming to manage the impact on the labor market and society. The model suggests a lag or a gradual approach to regulation, which may be due to bureaucratic inertia or a deliberate phased approach to implementing regulations.

The employment level initially decreases, which could be due to AI adoption's impact on the labor demand [17]. However, it stabilizes and does not drop below a certain threshold, possibly due to the employment threshold parameter that prevents employment from falling too low. This could represent social safety nets or policies that maintain a minimum level of employment regardless of technological impact.

In practical terms, these trends could inform policymakers about the importance of:

- Ensuring that education leads to the acquisition of relevant skills in demand in an AI-driven economy.
- Monitoring the impact of AI on employment and being ready to intervene with policies to support those displaced by technology.
- Planning for a future where AI is more prevalent and ensuring that regulations are adaptive and responsive to the pace of technological change.
- Supporting continuous learning and skill development to maintain employability in a changing labor market.

6 Conclusions

This paper describes an agent-based model (ABM) to predict the social and economic consequences of using generative artificial Intelligence (AI). Through simulations conducted using the proposed model, we have explored the potential impacts of generative AI adoption on various societal factors, including education, employment, and government regulation. Our simulations have provided insights into the dynamics of generative AI adoption and its interactions within socio-economic systems. We have observed trends such as the increasing adoption of AI by businesses as the population's skills improve and the potential implications for employment levels and government regulation. Key Findings:

- Education and Skills Development: The simulation revealed a logistic growth in education and skills levels, pointing towards a saturation point beyond which additional education does not proportionally enhance skills. This suggests the need for optimizing educational resources and strategies to maximize effective learning and skill acquisition without unnecessary overextension.
- AI Adoption Trends: AI adoption was observed to increase steadily, influenced by the availability of skilled labor and regulatory frameworks. This underscores the importance of aligning educational outcomes with market needs, ensuring that the labor force is equipped to handle and benefit from emerging AI technologies.
- Regulatory Dynamics: The gradual increase in regulatory measures in response to AI adoption highlights the necessity for governments to adopt a proactive and phased approach to regulation. This strategy allows for the accommodation of technological advancements while ensuring that societal impacts are managed and mitigated.
- Employment Impact: The initial decline followed by stabilization in employment levels indicates the disruptive impact of AI on traditional jobs, countered by employment policies possibly designed to uphold a minimum level of workforce engagement. This aspect of the findings stresses the importance of having robust social safety nets and policies that can adapt to technological disruptions.

Based on the findings of this study, we recommend the following actions for stakeholders:

- Educational Policy Reform: Policymakers should focus on revising educational curricula to emphasize skills that are directly relevant to an AI-driven economy. This involves not only technical skills related to AI and data science but also adaptive skills such as problem-solving, critical thinking, and lifelong learning capabilities.
- Strategic AI Integration: Businesses should strategically adopt AI technologies, with a focus on augmenting rather than replacing human labor where possible. Investment in employee training to work alongside AI will be crucial for maximizing productivity and innovation.
- Proactive Regulatory Frameworks: Governments should develop flexible, forward-looking regulatory frameworks that can quickly adapt to new developments in AI technology. This involves regular dialogue with technologists, business leaders, and academics to anticipate future trends and potential impacts.
- Support for Displaced Workers: There is a pressing need for policies that support workers displaced by AI, such as retraining programs, unemployment benefits, and career counseling services. These programs should be designed to quickly and effectively re-integrate workers into the evolving job market.
- Lifelong Learning Systems: The development of continuous education and training systems is essential. These systems should be accessible to all workers throughout their careers, allowing them to continuously update their skills and stay relevant in a rapidly changing economic landscape.

However, it is essential to note that our model relies on certain assumptions and parameter values that may not fully capture the complexity of real-world scenarios. In future work, there is a need to refine and validate the model by estimating parameters based on real-life statistics and data. We can enhance the model's predictive accuracy and reliability by calibrating the model to fit empirical observations better.

Additionally, future research could explore the long-term implications of generative AI adoption, considering technological advancements, societal attitudes, and regulatory changes. Furthermore, there is a need to assess the potential ethical and moral implications of using generative AI, including bias, privacy, and accountability issues. Our study represents an initial step toward understanding and predicting generative AI's social and economic consequences. Refining and expanding our model in future research can further advance our understanding of this rapidly evolving technology and its impact on society.

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Fight Food Waste and Promote Healthy Regional Cuisine Through a Mobile APP

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Abstract. Sustainability is a word on the agenda in several aspects of modern societies. With regard to the food component, it is increasingly important to combat food waste, not only due to the imbalance it creates in global food needs, but also due to the effect of producing waste that has to be processed and has a negative environmental effect. This paper presents a multiplatform mobile application that aims to promote the fight against food waste, while promoting healthy and sustainable cuisine based on typical recipes from the Trás-os-Montes region. This approach promotes the fundamental triangle composed of the vertices of sustainability, health and regional promotion.

Keywords: Sustainability · Food Waste · Health · Regional Cuisine · ICT Application

1 Introduction

According to the Food and Agricultural Organization (FAO) of the United Nations, around one-third of food intended for human consumption is lost or wasted worldwide each year [1]. Some studies have highlighted the fact that households are the main responsible of the current high amounts of food waste detected over the last decades in industrialized countries [1, 2].

While not mentioned or known as much like Water Pollution or Air Pollution, Food waste also have an equally negative effect in our planet, with strong consequences from the environmental point of view [3, 4] the impact of food waste is quantified as corresponding to 8% of the global greenhouse gas emissions, 20% of freshwater consumption, and 30% of global agricultural land use [5].

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There are also studies that have identified some of the determinants and habits of consumption that can affect the generation of food waste. However, the creation of routines for shopping and reuse of leftovers were reported as some of the main drivers for food waste prevention, while planning routines only contributed rather indirectly. On the other hand, no significant association was established between household skills and shopping routines, although these skills did make an indirect contribution through planning routines [6]. Bravi [7] also reported that the reutilization of leftovers aids in preventing and reducing food waste. Additionally, unplanned food purchases typically made consumer buy unnecessary products or in larger quantities than necessary/recommended which ended on an involuntary and unconscious increase of food waste [7]. In [8] the authors highlighted similar conclusions: consumers who have accurate planning skills and habits, who can cook creatively and effectively with leftovers and who know better how to prolong the shelf life of products, as well how to preserve natural aliments are more propitious to waste less food.

Over the last years, several mobile apps claiming to contribute and promote the mitigation of the food waste have been developed and are currently available to be downloaded and used by consumers [9] to both mobile platforms. However, most of those applications are aimed to promote and highlight supermarkets, food shops, and restaurants where consumers can get the surplus food, this is, leftovers which these businesses are unlikely to sell until the end of the day, preventing then the waste of large volumes of food as well the contribution for the general pollution.

A recent study explicitly linked home cooking practice with healthy behaviors [10]. Therefore, the practice of cooking at home seems to be important in the context of having a healthier lifestyle, this is mostly because of being able to have a better control over the use of spices as well the quantity of salt, which tends to be used in higher volumes than recommend to highlight the food taste, other variable to which a person is expose and don't have direct control when eating outside is the kitchen itself, while there are a restrict control over the conditions of those kitchens, over the time is consecutively being found failures, negligence and human errors which reflect on prejudices in the clients health.

However, whether for health reasons like intolerance to certain foods, the daily routine and limited available time or simply because the person does not like the practice of this activity, it's not always easy to come up with ideas about what to cook, principally on a way to be effective, healthy and wasteless.

The aim of this project is to propose an application which, on one hand, combats food waste, focused on a homemade meal scenario, and in the other hand, also provides the user with recipes based on certain personal characteristics, like chosen lifestyle or food intolerances (e.g. diabetes).

2 Methodology

The work presented was the result of a partnership with the Municipality of Mirandela (a city located in the Northeast of Portugal and highly regarded by her local cosine and natural products) and was planned by a multidisciplinary working group composed by members of local entities, which included, in addition to the ICT technical team,

specialists in the areas of gastronomic training, nutrition and municipal management. This team held a series of meetings to establish the requirements of the application to be developed and, in parallel, several recipes were designed, the aim of which was to make use of leftover food or fresh ingredients, which were subsequently reviewed and cataloged nutritionally by a nutritionist, these same recipes would also be prepared and photographed, photography's which were then to be used in the developed application, providing a realistic and original image/representation of the expected result from the recipe.

A vision of promoting regional products and the use of typical recipes from the region was also incorporated, as a way of promoting the products and gastronomic culture of the Trás-os-Montes region.

All development phases were monitored by the entire team, which validated the implementation process, in light of the specified requirements (functional and non-functional). Finally, after completed the implementation of the mobile application, a test group was created so that the application could be thoroughly tested, in order to incorporate the team's feedback and arrive to a final product, being planned the launch as part of a local event and to be publicly available in the main applications stores.

3 Developed ICT Application

As a solution for the presented problem, it was decided to develop an Information and Communication Technology (ICT) application focused on the use of Information Technology (IT) and Mobile Technology, in a way of being able to store and provide information on a local and offline setup, while being highly accessible, in terms of hardware.

3.1 Plannification and Requirements

The stage of planification was done based on reunions with the involved entities, which included schools (with restauration curriculums), the municipality, a local health center and others, being settled as primary the goal the promotion of sustainability through a good use of fresh ingredients and reutilization of leftovers, to minimize waste, as well to educate and orientate the user through a healthy alimentation by giving tips and professional health insight.

Based on the outcomes from the meetings, the following Use Cases Diagram in Fig. 1 was designed, being "Use Case" a representation of a task/functionality from the User point of view.

The present Use Cases have as their goal the fulfillment of the requirements, however for better usability and popularization other features were added such as "Share Recipe" or "Preparation Guide".

Among those Functional Requirements defined during the meetings, the core ones are listed and explained in Table 1. Aside from the Use Cases which can also be described as Functional Requirements, it was also defined some Non-functional Requirements (see Table 2).

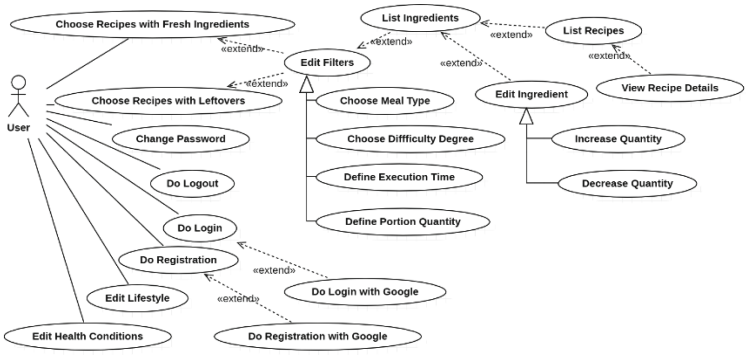


Fig. 1. Core Use Cases Diagram.

3.2 Architecture

In the Fig. 2 is presented the Architectural Model of the conceptualized ICT Application based on the defined requirements while also projected to be simple and to work on a closed circuit, being decided the development of a mobile application able to run in both platforms, this is, iOS and Android with the goal of reaching the maximum of users.

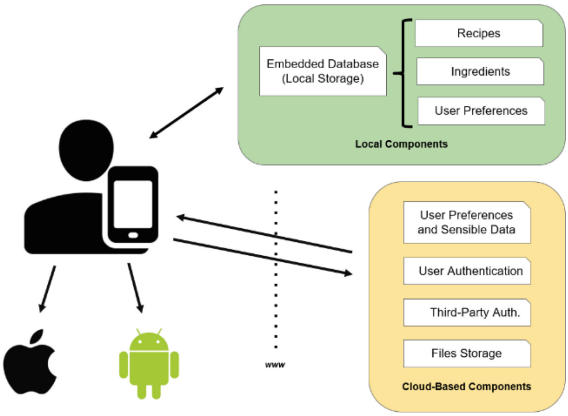


Fig. 2. Architecture Model.

Relatively to the components that build the core of the application, it can be divided into two groups, Local Components and Cloud-Based Components, the first group refer to the components incorporated in the device, being constituted by an Embedded Database for Local Storage of the data, which is mainly relative to the Recipes.

The second group englobes components which were decided to be cloud-based, being them services provided by third parties entities, this methodology was chosen to avoid the necessity of setting up a dedicated server which would increase the difficulty of the project. Some of those components are projected to enable future improvements,

Table 1. Core Functional Requirements.

Label	Description
Define lifestyle / diet	The user must be able to define their lifestyle/diet (defined as options: omnivorous, vegetarian and vegan), in which omnivorous is used as default, in order to filter the recipes presented
Define health conditions / limitations	The user must be able to select their health conditions/limitations, these do not limit the recipes presented, indications/suggestions will be presented depending on the selected options. "Diabetic" and "Hypertensive" were defined as valid options
Choose between recipes based on Ingredients (to be cooked) or Leftovers	The user will first choose between Recipes based on Ingredients (for cooking) or Leftovers, this being the first choice to be made by the user in the main flow of the application
Choose Ingredients / Leftovers and Respective Quantities	The user should be able to choose which ingredients/leftovers to use in order to filter the recipes to be presented to only recipes that contain any of the chosen ingredients/leftovers. The selected quantity will not filter the recipes presented
List Recipes	After choosing the ingredients/leftovers to be used and based on the filters, the user must be presented with a list of available recipes, this list must contain at least the name of the recipe and its respective photograph/image
View Recipe Details	The user must be able to view the recipe details/information, which, as default, must include: • Photo (Original)/ Main Ingredient Image; • Name of the Recipe; • Execution Time; • Preparation Time; • Number of People/Portions; • Difficulty Level; • Name of the Author Entity; • List of Ingredients; • Suggestions/Recommendations (Chef and Health Professional); • Method of Preparation; • Video (located on the Web);

such as the ones related to an User Account, while others are projected to minimize the size of the application (*Files Storage*).

Table 2. Non-Functional Requirements.

Label	Description
No restrictions on the e-mail used for registration	The user will have no restrictions on the e-mail/email provider they can use to register
Login valid for unlimited time	Once you have logged in, there is no validity period, so you don't need to log in again unless the user in question logs out
Dynamic Recipes	The content of the application should not be static, but it should be possible to add recipes to the application through updates, without affecting the user or requiring specific interactions on the part of the user within the application
Local food	Ingredient names from brands/production in Northeast Transmontano/Mirandela should be used when possible
Prioritize seasonal foods	Recipes that use seasonal foods, selected by the user, should have a certain priority in the list

3.3 Applied Technologies

The default scenario when developing applications targeted to both mobile Operative Systems (OS), iOS and Android, is the development through the use of native programming respectively, Swift/Objective-C and Java/Kotlin, this however requires a wider range of skills and knowledge as well equipment, being another alternative the use of cross-platform frameworks.

Those frameworks were created with the goal of providing developers the ability to develop for different mobile platforms with just one programming language and tool being then compiled into native code of the respective platform, this concept first surged in 2008/2009 through the open-source framework Apache Cordova (CallBack), later known as PhoneGap when acquired by Adobe in 2011, others big companies followed the popularization of this technology like Microsoft when acquired Xamarin in 2016, which was founded in 2011 by Miguel de Icaza and Nat Friedman. While cross-platforms frameworks have certain limitations, they represent an easier, faster, and more accessible way of development, able to be used successfully in many kinds of projects.

Nowadays the most famous used ones are Flutter which uses Dart as programming language, released in 2017 by Google, and React Native from Facebook. The latter was released in 2015 and makes use of JavaScript and/or TypeScript, having as base the same concept and methodology of development used in React.js (2013) and Next.js (2016), both frameworks from Facebook for Frontend Web Development, which makes

React Native the better choice for future prospectives, as well for using a programming language widely used for Backend Development.

When developing with React Native, a developer can use React Native Command Line Interface (CLI) or Expo, being the CLI alternative a tool provided by React Native team for initializing, building, and running React Native projects, offering more flexibility, control over the environment and capacity of customization by modifying native code (Android and iOS), contrary to Expo, which on the other hand provides a set of pre-configured tools, libraries and Application Programming Interfaces (APIs) with the goal of simplifying the development while having more limitations that React Native CLI, like in the access to native modules. Due to not being required a deep control over the native code it was chosen the use of Expo instead of React Native CLI.

In terms of data storage, the current requirements can be achieved through the use of an Embedded Database, this kind of database is commonly and widely used by mobile applications and is the opposite of the more known Server-Side database, focusing in storing data locally, instead on a remote server, for future consult without requiring connection to the Internet, while existing a wide range of types of Embedded Database it was used SQLite, a Structured Query Language (SQL) database released in 2000.

However, while the core data of the application can be stored locally, user related data and files were to be saved online for updated access across devices, in a way to avoid the necessity of developing a Web API or similar solutions, it was used the NoSQL cloud-hosted database from Google, Firestore, which stores data as JSON files, and is commonly referred as a Document Database like others well-known like MongoDB. This service as well others also used like Authentication (for Google Sign-In) and Storage (for images storage) are part of the known package Firebase, a group of backend cloud computing services for faster development. These services are supported by React Native and can be used easily without requiring Backend Development knowledge.

Aside from SQLite it was also used AsyncStorage, a package from React Native which consists of providing a Key-Value Database, while under the hood uses a serialized dictionary in iOS or RocksDB/SQLite in Android.

3.4 Data Layer

To achieve the pretended functionalities the following database was designed (see Fig. 3) in which the data surrounds and complements the main table, *Recipe*, where is stored data directly related to the recipe. Each recipe is associated with a type of meal and is separated by using “leftover” or “fresh ingredients” through the integer attribute *ingredientType*.

Relatively to data storage technique it was decided to use a hybrid methodology, by dividing the core data, that is, the data related to the recipes and expected to be accessible anytime, from the user data, which would be available, updated, across devices. The core data would be saved in the Embedded Database while the user relative data would be stored in the cloud-hosted database, while keeping a copy of data related to lifestyle and health conditions in the Embedded Database.

In general, the data behaves similarly between the two types of recipes, the distinction being made by the logic implemented and the flow of the application. Aside from the types of recipes, each one also contains nutritional information provided by a professional nutritionist and observations related to the recipe provided by the respective chef (entity

responsible for the recipe) or related to health conditions, in which are provided by a health professional, for the current stage it is being tested with just two of the more common conditions, being analyzed the future inclusion of other conditions as well the possibility of defining allergies.

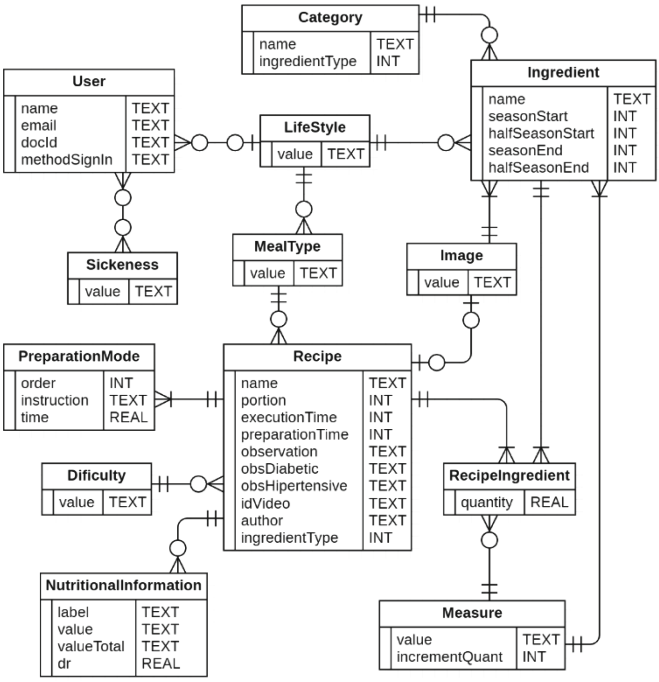
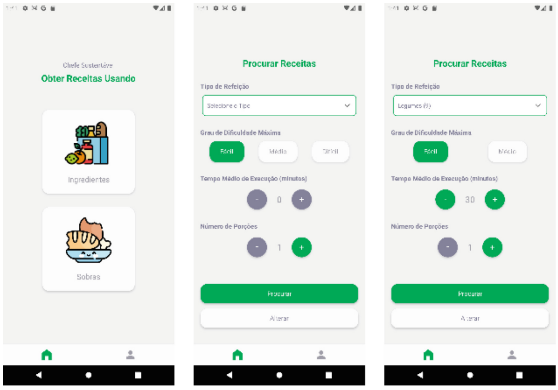


Fig. 3. Embedded Database (SQLite) Entity Relationship Diagram.

3.5 Implemented Features

Based on the defined requirements, the principal features which were implemented can be grouped as follows.

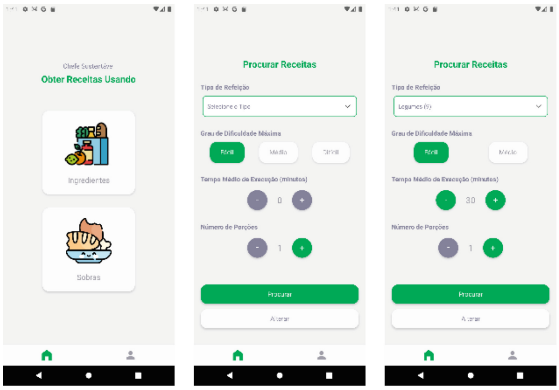
- **Selection between Recipes based on Leftovers or Fresh Ingredients** (see Fig. 4) in which consists in the ability of the user to select if wants to find recipes based on the use of leftovers from previous meals, or fresh ingredients, after which will be able to define filters.
- **Recipe Filtering** (see Fig. 4) where the user can select the type of meal, time and degree of difficulty, being these considered "hard filters", since it will limit the quantity of available recipes, on the other hand, the user will also be able to select the quantity of portions/people desired, which will work as a "smooth filter", only being used to calculate the difference between the total necessary quantity of ingredients and the quantity available to the user, with the goal to give priority to those which will make better use of the ingredients.



a) b) c)

Fig. 4. Android Simulator Screenshots: a) Recipe Type Selection and b) Filtering.

- **Ingredients Selection** (see Fig. 5) will be available to the user after selecting the filters, being based on the ingredients used by the recipes that fit the defined filtering, aside from selecting (deselecting or modifying) which ones to use, as well the quantities, the user can also check the selection through a listing.
- **Recipes Listing** (see Fig. 5) will display all recipes which fits the filters and uses the selected ingredients, ordered by the better degree of use/reuse of ingredients based on the available ingredients and quantity necessary, taken in account the quantity of portions selected previously.

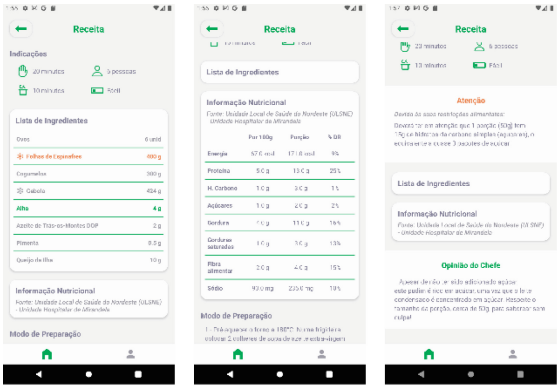


a) b) c)

Fig. 5. Android Simulator Screenshots: a) Ingredients, b) Recipe Selection and c) Recipe Details.

However, it is also considered the ingredients season, being given priority to the recipes using seasonal ingredients based on the current time of the user acquired from the device.

- **Recipe Details** (see Fig. 5 and Fig. 6) consist in displaying the basic data of the recipe, such as time and preparation mode, but also data related to observations, in which will adjust to the health conditions of the user, it will also be displayed the nutritional information.



a) b) c)

Fig. 6. Android Simulator Screenshots: a) List of Ingredients, b) Nutritional Information and c) Observations/Alerts.

Together with the listing of ingredients will also be highlighted the previously selected ingredients that are being used and it will be distinguished between ingredients in which the available quantity fills the necessary one, calculated in the code, and which not.

Independently if the ingredient is being used or not, it will also be added a visual symbology to seasonal ingredients, these being a season representative icon. This has the objective of preventing the user about ingredients which can be more expensive at that time while also encouraging him to make use of ingredients that can be found in abundance, and which may not have a long shelf-life expectancy, at least not naturally and in a healthy way.

- **User Account**, in which the user can create an account and manage his data, currently being concerned only with his health conditions (e.g. diabetics) and lifestyle choices (e.g. vegetarian) as seen in Fig. 7.

Aside from the described features/functionalities, it was also implemented features more directed to the usability of the application, such as “night mode”, being also tried the inclusion of Deep Linking in the “Share Recipe” functionality, which refers to the ability of navigating through an application (if installed) or in being redirected to the store where the application is located (e.g. Google Play Store in Androids or Apple Store in iOS), similarly to how hyperlinks work with websites.

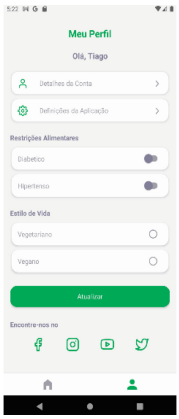


Fig. 7. Android Simulator Screenshots: Health Conditions and Lifestyle Selection.

4 Conclusions

The present work fulfills the current requirements of promoting sustainability through a better use of ingredients and reutilization of leftovers while also proving health related inputs.

Whenever the application is installed on a device, a local database (SQLite) is created, and all data related to recipes is inserted into it.

If the user decides to register, the application first checks whether the user is already registered in the Firestore. In case he is already registered, the application displays a message informing that the user is already registered. If the user is not registered, the application inserts the user data into the Firestore and in the local database.

If the user decides to log in, the application checks whether the user exists in Firestore. If the user exists, it is inserted into the local database and its data is saved into the local database. When the user logs out, their data is deleted from the local storage.

On the other hand, if the user decides to log in with their Google account, or if they wish to register with Google, the user is entered into the database.

Relatively to the Recipe information, it is stored in the local database. As it is a local database, each device has its own database.

Future work includes the registration of the recipes used and the creation of a historic to calculate and provide the user insights about their degree of sustainability and good utilization of ingredients. On a different level, through the registration of the recipes made, it will also be possible to promote a healthier alimentation through the calculation of the nutritional information, generating suggestions based on the user history.

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Use of Extended Reality in the Tourism Sector: A Bibliometric Analysis Across Scopus and Web of Science Over the Last Ten Years

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Abstract. Extended reality is an emerging technology that has evolved significantly in recent years. However, its state of maturity is quite different depending on the economic sector where it has been applied. The tourism sector, where company/people communication is a key factor and where one of the main products to be sold are "destinations", makes exciting the role that extended reality can play in creating innovative solutions at the service of the sector and of its customers, who are global. This paper presents a bibliometric analysis based on Web of Science and Scopus sources, presenting an overview of the last ten years of R&D in extended reality applied to the tourism sector. The results obtained are discussed as a contribution to understanding patterns and/or trends that could help actors in the tourism sector and developers of extended reality solutions.

Keywords: Extended Reality · Virtual Reality · Mixed Reality · Augmented Reality · Tourism · Bibliometic Analysis

1 Introduction

Extended Reality (XR) and the main technologies that support this concept, such as virtual reality (VR), augmented reality (AR) and mixed reality (MR), constitute a new paradigm that contributes to a greater and more improved support for industry 4.0 [1]. The areas of R&D application of XR are multidisciplinary, extending from the primary sector (e.g. agriculture, aquaculture) [2], health and caregivers [3, 4], the education sector [5, 6] or tourism [7, 8], among many others.

The tourism sector has greatly expanded technology adoption. Not only due to the increase in actors who started to include more technology in their business processes

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but also due to the increased use of technology as an innovation strategy, especially for customer interconnection services.

According to [9], the number of tourist destinations that have been using smart technology to enhance the visiting experience has been increasing, and tourism R&D has highlighted the role of information and communication technologies in improving tourist experiences.

As tourism is a sector that has grown substantially and represents great economic importance for many countries, it becomes pertinent to understand how extended reality, in its various variants, has been used in the tourism sector, as well as what type of R&D has been carried out.

The specific objectives of this bibliometric analysis were to identify, according to the sources and time frame under analysis, how scientific production evolves, which were the most active authors and institutions, the most relevant sources, as well as the detection of trends and/or or research standards. After framing the theme under analysis, the methodology used in the research, selection, treatment and analysis of the data is then presented, then the results are presented and discussed and, finally, some final considerations are presented in the conclusion.

2 Methodology

This research, done during February 2024, has the goal of identifying the primary concerns and appliances of Extended Reality (XR) in the Tourism sector, as well as identifying the pioneers in this field of research in the last 10 years (2014 - 2023) focusing only on articles indexed in the two most famous databases, Web of Science (WoS) and Scopus. Research published in 2024 (January and February) was also included since, at the moment of this research, while published in 2024, technically the work done occurred during the defined period.

XR is a term, initially, used to englobe technologies such as Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR), however it has become a more general terminology, incorporating all technologies concerned with the merging of the Real and the Virtual world, such as Spatial Computing. This "definition" can be considered quite recent, following Google Trends insights, the topic "Extended Reality" has started to become more popular surrounding June 2021, which can affect its appliance and use in scientific research.

In a first stage (see Fig. 1) it was done a search surrounding the topics "Tourism" and "Extended Reality", present in the Title, Keywords and Abstract, which resulted in 13 articles from WoS and 15 from Scopus, in a total of 18 articles after merging duplications by using Zotero. The search result was low as it was expected due to the mentioned low popularity of the term "Extended Reality" in scientific research, however it can be seen an increase in the use of the term starting in 2021 with 3 articles, going for 6 in 2022 and 9 in 2023.

XR, when used, tends to refer to the use of two of the technologies or only one, being few the research's concerning the three at the same time. In this way, the second stage specified the use of each technology, separately.

Regarding the use of AR in the Tourism sector it was found a total of 412 articles (297 from WoS and 290 from Scopus) while its counterpart, VR, marked presence over

648 articles (being 452 from WoS and 505 from Scopus), this comparison may however translate into misconceptions since the term AR has a considerable presence over the results related to VR articles, a similar occurrence was also detected in the AR articles.

In terms of MR, it was found 53 articles, from which 35 are from WoS and 43 from Scopus, like XR, MR is also considered a recent term and it is still not well established, this situation also results in problems where AR is a term highly present in the articles, this occurs also duo being a term commonly used as substitute/synonym of MR.

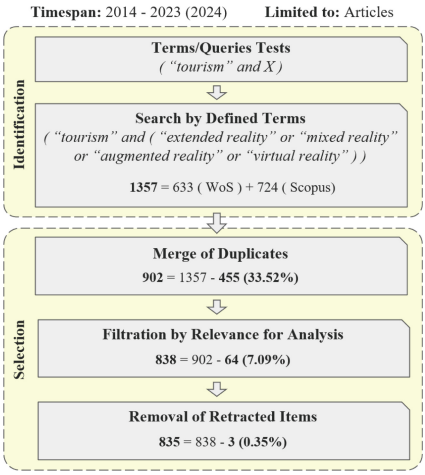

Fig. 1. Flowchart of the process of the article's selection for the Bibliometric Analysis.

For a better and comprehensive understanding about the use of XR in Tourism it was decided to join all results from the previous searches ("XR or MR or VR or AR"), which were using the selected terms either in the Title, Keywords or Abstract, as well to select all available information from the databases, resulting in a total of 1357 articles, value reduced to 902 articles after merging 633 articles from WoS and 724 articles from Scopus through the use of Zotero, being detected 455 (33.52%) duplicated articles.

After the merging, it was done a selection among the viable articles with the objective of avoiding papers which could interfere with the analysis such as others bibliometric analysis, literature and systematic reviews, or articles which could not be related to the pretended topic to be analyzed, the use of XR in Tourism, this selection was done based on the article titles, keywords, and in ambiguous cases, through the reading of the abstract, which resulted in the exclusion of 64 articles (7.09%), followed by an exclusion of 3 articles which were tagged as retracted by Zotero.

Based on the selected articles it was used as tools the ScientoPy [10], Bibliometrix/Biblioshiny [11] and VOSviewer [12] to do a bibliometric analysis. Each tool provides a different set of graphs and insights, as such the three tools are used to complement each other. Both ScientoPy and Bibliometrix are able to merge data from WoS and Scopus, however it was found a discrepancy in the number of articles used for analyse, while ScientoPy ended up with 897 articles, the same data merged by Bibliometrix resulted in 922 articles, such discrepancies may occur due to how data, like titles with

special character, is treated in each database, as such it was used the resulted data from the merge in Zotero (where is done one by one based on human choice) as base, being the files processed from ScientoPy and Bibliometrix reviewed before the analyze, it was also used Zotero to generate a *.ris* file viable for the use of VOSviewer.

3 Results and Discussion

In Table 1 is presented a minimized overview of the selected articles, based on the data generated by Bibliometrix, it can be seen than 88.36% of the articles were written in co-authorship with an average of 3.47 authors per document, being 7.06% of the articles results of international cooperation. It was also identified a total of 2455 author's keywords and 2077 keywords plus.

Table 1. Data Overview (Bibliometrix).

General Information		Authors	
Timespan	2014:2023(24)	Authors	2246
Sources	388	Authors of single-authored docs	91
Annual growth rate %	9.48%	Single-authored docs	93
Document Average Age	3.11	Co-Authors per Doc	3.47
Average Citations per Doc	21.5	International co-authorship %	7.06%
Total References	41672		

When searching articles in both databases about the first reference of XR it refers to an article centered on the adoption of AR in 1982, while Tourism dates to 1947, however, the oldest article combining both terms dates to 1995 both in WoS and Scopus, concerning the impact of VR in Tourism, since then Scopus indexed 780 articles, while WoS indexed 663 articles. Considering the timespan defined for this bibliometric analysis it can be noted that 92.82% (Scopus) and 95.47% (WoS) of the current indexed articles surrounding XR and Tourism, including the excluded for this analysis, were produced in the last ten years.

Over those years the increase of articles is notable, with an Annual Growth Rate of 9.48% and, as seen in Table 2, the number of articles indexed by 2024, a total of 47 articles by February, is already surpassing 2018 and years before. This evolution along the years in the last decade shows that XR is being considered an important technology for the future of Tourism, being VR the one seen with more potential and impact in this sector.

Among the ten principal sources (see Table 3), both in number of articles as well by the Bradford's Law, over the 388 detected sources, the principal one with a total of 47 articles is Sustainability, an open-access, international and peer-reviewed journal that has an Impact Factor of 3.9 (2022) and Citescore of 5.8. The second one, with a difference of 17 articles is Current Issues in Tourism, also an open access, international

Table 2. Annual Scientific Production (Bibliometrix).

Year	Articles	Year	Articles
2014	19	2020	98
2015	16	2021	120
2016	17	2022	164
2017	31	2023	206
2018	43	2024	47
2019	74		

Sources

and peer-reviewed journal that has an Impact Factor of 8.0 (2022). However Current Issues in Tourism was the first journal publishing articles concerning XR, in 2014, while Sustainability started only 2018.

Table 3. Annual Scientific Production (Bibliometrix).

Source	Nº of Articles	Impact Factor by Journal Citation Reports (2022)
Sustainability	47	3.9
Current Issues in Tourism	30	8.0
Tourism Management	19	12.7
Journal of Hospitality and Tourism Technology	17	4.7
Information Technology & Tourism	17	9.3
Applied Sciences-Basel	14	2.7
Journal of Heritage Tourism	13	2.7
Journal of Travel Research	13	8.9
Journal of Destination Marketing & Management	12	8.4
Journal of Hospitality and Tourism Management	10	8.3

In terms of local impact among the selected articles, the leading ones are *Current Issues in Tourism* and *Tourism Management*, both journals with a h-index of 16 followed by *Sustainability* with a h-index of 15.

However, the one with a bigger Impact Factor among the ten principal sources is *Tourism Management* with 12.7, while also being the third source with more articles, as well the source with most local cited sources with a total of 682 citations. According

to Elsevier, *Tourism Management* is also the leading scholarly journal focused on the management of travel and tourism.

3.1 Subjects

Relatively to subjects, as it can be seen in Fig. 2, *Social Sciences* has been a primary topic of discussion since 2017 followed, with a large margin, by *Business & Economics*, others topics more related with technologies or arts seem to not be considered priorities so far in the conjunction of XR and Tourism, this may mean that the current concerns reside in how the human will behave and adapt with this new technology as well on how it will impact this sector at an economic level, instead of worrying about the availability and limits of the current technology as well future progress.

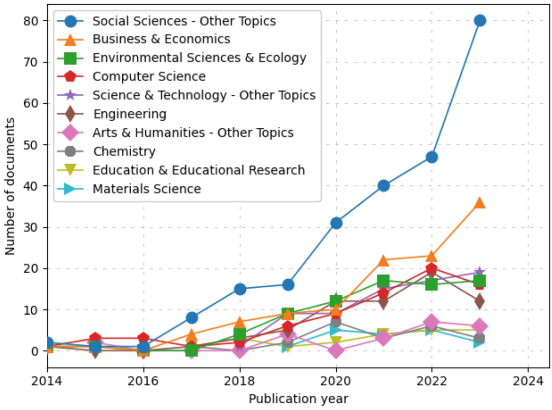

Fig. 2. Subjects Interest Timeline (ScientoPy).

3.2 Authors

In terms of Authors (see Table 4), Dr. Timothy Jung, Founder/Director of Creative AR & VR Hub in the Manchester Metropolitan University, and owner of a Highly Cited Researchers 2023 Award by Clarivate Analytics, is the leading one with a total of 29 articles, followed by Dr. M. Claudia tom Dieck, also a member of Creative AR & VR Hub, with 17 articles and Dr. Yanyun Wang from the University of Colorado, with 12 articles.

Dr. Timothy Jung is also the leading author in local cited authors with a total of 50 local citations among the selected articles followed by Dr. Choong-Ki Lee (Kyung Hee University) with 40 citations and Dr. Namho Chung with 33 citations.

Table 4. Ten Most Relevant Authors (Bibliometrix).

Author	Articles	Articles Fractionalized
Jung T	29	8.22
Tom D M	17	5.50
Wang Y	12	2.96
Li Y	11	3.01
Zhu C	10	2.55
Chung N	8	2.17
Han D	8	2.32
Bessa M	7	1.26
Chen C	7	1.51
Flavián C	7	1.80

3.3 Affiliations

In relation to affiliations, Manchester Metropolitan University (United Kingdom (UK)) is the most relevant affiliation with a total of 56 articles, closely followed by Kyung Hee University (South Korea) with 28 articles, both universities are also the affiliations with the most productions over time, with the Manchester Metropolitan University as the principal one. Hong Kong Polytechnic University (China) stands as the third most relevant affiliation with 20 articles, having started to show investment in this topic starting in 2021, when still only had 8 articles.

It can also be seen (see Fig. 3) a strong collaboration between those two affiliations, the UK, and South Korea universities, standing out from other collaborations.

Fig. 3. Collaboration Network between Affiliations Walktrap Algorithm (Bibliometrix).

3.4 Countries

Regarding countries, UK stands as the country with more citations, with a total of 3349 citations, followed by Korea (2238), USA (2095) and China (1653), however UK, by 2023 only had a total of 75 articles, while China had 215 articles, being also the country

with the biggest increase on productions over time by a large margin, starting to standing out from the others countries in 2020 when only had 32 articles while UK had 28 articles and USA had 27 articles.

In the Fig. 4 it can be seen the principal collaborations between countries, being highlighted China as the country with most productions over international collaborations, in particular with Korea and UK, who stands as the second principal country and who also have a strong relationship with Korea.

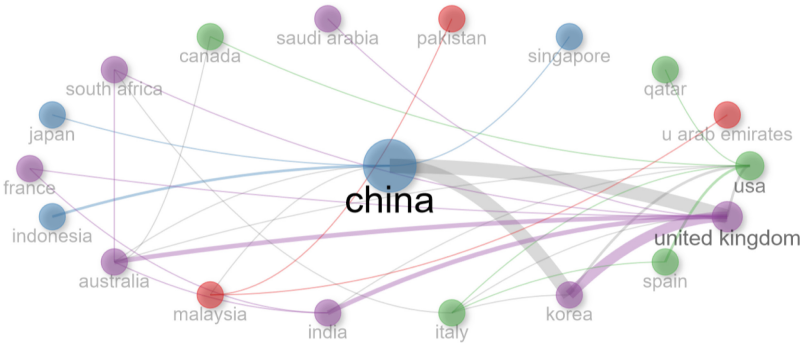

Fig. 4. Collaboration Network between Countries with Walktrap Algorithm (Bibliometrix).

3.5 Keywords/Terms

Relatively to Author Keywords (see Fig. 5), after merging some related keywords (e.g. vr / virtual-reality / virtual reality) present on the TreeMap, VR stands as principal used keyword with 320 articles, followed by AR with 198 articles, this proves the interest by researchers in the use of VR in Tourism over AR or MR, other keywords that are highlighted are per example, heritage (red), marketing (pink) and virtual tourism (purple), other one is covid-19 (brown) which is a consequence of the recent pandemic (2019–2021) and who created new concerns across a variety of fields and research areas. In general, these keywords show an interest in using VR to promote tourism, keep and improve heritage tourism as well to enable tourism on a virtual level, with the possibility of creating scenarios and use cases which would not be possible otherwise, duo to practical or financial limitations.

Others interesting keywords are sustainability (lemon-green) and smart tourism (light purple), which means that researchers are seeing XR as technology which can bring Internet of Things (IoT) to the tourism sector as well as technology that can improve the footprint. The human aspect is also marked as a concern and discussed topics through keywords like satisfaction (light blue), user experience (light pink), telepresence (light brown), and authenticity (dark green).

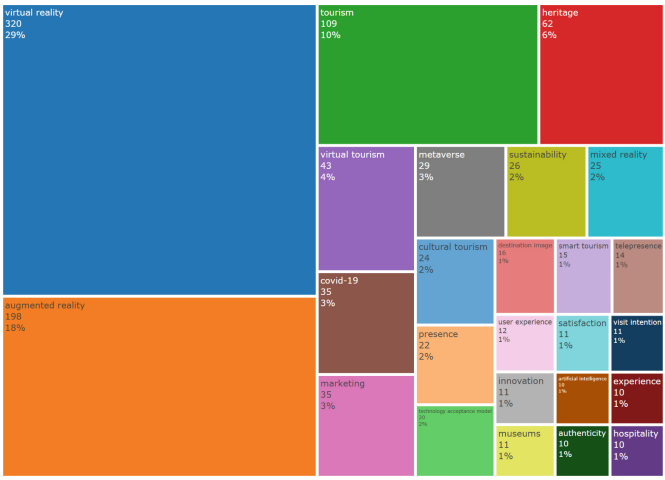

Fig. 5. Author Keywords TreeMap (Bibliometrix).

While heritage (9th) and marketing (10th) are shown still as important topics of research, the trends (see Fig. 6) point out that virtual tourism (1st) is the "topic of the moment" having his culminating point in 2023 while the others were in 2021 and 2020 respectively, however heritage is still widely present in recent articles. In other hand, a topic that shows potential for next year is metaverse (2nd / dark grey), sustainability (6th) also appears as relevant in recent years.

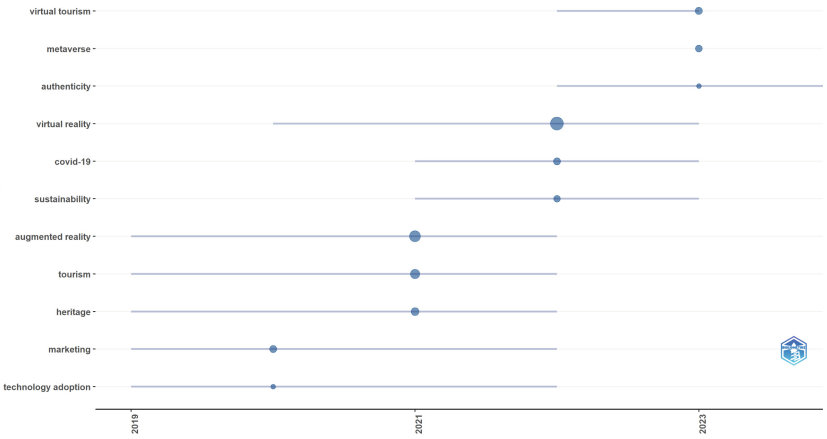

Fig. 6. Author Keywords Trend (Bibliometrix).

In Fig. 7 can be seen that the keywords virtual tourism and telepresence are currently considered as motor themes in the integration of XR into the Tourism sector, followed by topics like user experience and satisfaction which takes the human as an essential component and concern of this integration. Topics like artificial intelligence, marketing

and sustainability while also considered important are marked as transversal with other fields.

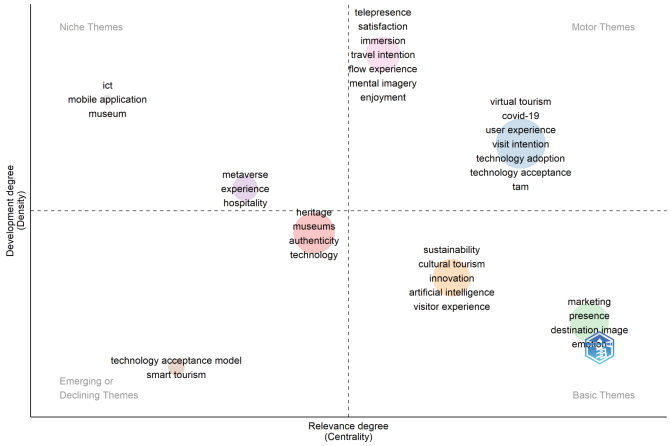

Fig. 7. Author Keywords Thematic Map with Louvain Algorithm (Bibliometrix).

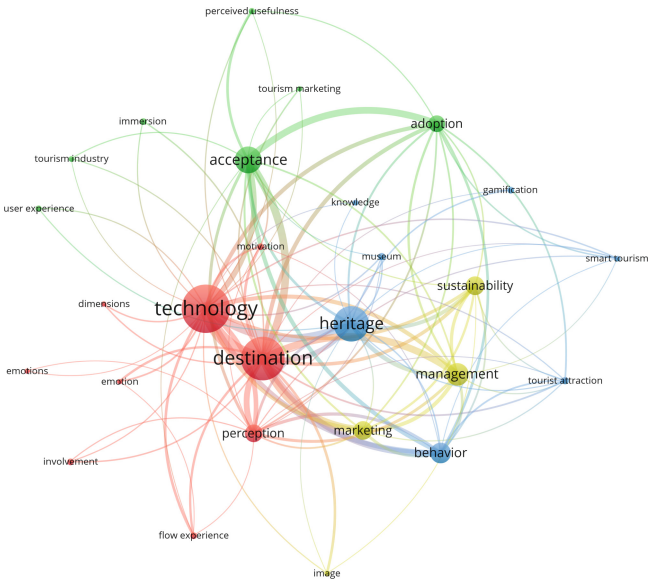

Fig. 8. Keywords Co-occurrence (VOSviewer).

When analyzing the thematic map is also noted the presence of technology adoption and technology acceptance in the sector of motor themes, while not positioned as highly

relevant, this may refer as them being some of the bigger constraints and obstacles for the use of XR.

Another way to analyze keywords is through the detections of co-occurrences, Fig. 8 is the result of finding keywords co-occurrence with a minimum of 15 occurrences across the articles and after being merged similar terminologies, it was also decided to exclude XR related terms for a cleaner analyze.

In a first analyze the highlighted keywords are technology, destination, and heritage, which again points toward a potential use of technology (XR) to promote/empower heritage tourism as well to be used for destination marketing (strong co-occurrence between destination - marketing). Aside from these keywords, acceptance and management are also keywords which stands out from others, the first having a strong co-occurrence rate with destination followed by technology, on the other hand management has a strong co-occurrence with destination and, while a little smaller, with technology and heritage.

On another level, acceptance, adoption, perception, and behavior are keywords with a certain relevant rate of co-occurrence with technology which can be related with concerns on how the human, as an important variable, will interact with this kind of tourism evolution, progress. Sustainability is again a keyword marking presence with relevant relationships with destination, technology, heritage, and management.

3.6 Articles

Regarding articles relevancy on a general level (see Table 5), at first place stands "Virtual reality, presence, and attitude change: Empirical evidence from tourism" [13] with 559 citations, an article written by Dr. Iis P. Tussyadiah (University of Surrey, UK), Dr. Dan Wang (Hong Kong Polytechnic University, China), Dr. Timothy Jung (Manchester Metropolitan University, UK) and Dr. M. Claudia tom Dieck (Manchester Metropolitan University, UK) was published on *Tourism Management* in 2018, and has as focus the study of the effectiveness of VR in inducing a favorable attitude toward tourism destinations and shaping intentions through the realization of two studies, one in Hong Kong with 202 participants and the second in United Kingdom with 724 participants.

Also, on relevant places is "Exploring Consumer Behavior in Virtual Reality Tourism Using an Extended Stimulus-Organism-Response Model" [14] with 538 citations, and "The impact of virtual, augmented and mixed reality technologies on the customer experience" [15] with 421 citations.

The first article was published in 2020 at the *Journal of Travel Research* and stands also as an example of the previously identified international cooperation, being written by Dr. Myung Ja Kim (Kyung Hee University), Dr. Choong-Ki Lee (Kyung Hee University) and Dr. Timothy Jung (Manchester Metropolitan University, UK). This article focuses on analyzing the visit intention with VR tourism through the capture of cognitive and affective responses, attachment, and authentic experience level with a Stimulus-Organism-Response (SOR) theory based theoretical framework.

The second article is from 2019, being published in the *Journal of Business Research* and was written by members of the University of Zaragoza in Spain, Dr. Carlos Flavián, Sergio Ibáñez-Sánchez and Dr. Carlos Orús. This article focuses on presenting and

providing explanations on the new concepts and perspectives (technological, psychological, and behavioral) involved with the appearance and popularity of the XR technologies (VR, AR, MR).

An article which stands out by having a relatively high rate of citations by year compared to the number of current citations is "Technological disruptions in services: lessons from tourism and hospitality" (60.67 citations per year) published in the *Journal of Service Management* in 2019 and focused on the exploration of critical technological advancements to analyze the impact on ecosystems caused by the new service innovations, including VR and AR.

Table 5. Ten Most Relevant Articles (Bibliometrix).

Paper (DOI)	Total Citations	Citations Per Year
TUSSYADIAH IP, 2018, TOURISM MANAGE (https://doi.org/10.1016/j.tourman.2017.12.003)	559	79.86
KIM MJ, 2020, J TRAVEL RES (https://doi.org/10.1177/0047287518818915)	538	107.60
FLAVIÁN C, 2019, J BUS RES (https://doi.org/10.1016/j.jbusres.2018.10.050)	421	70.17
BUHALIS D, 2019, J SERV MANAGE (https://doi.org/10.1108/JOSM-12-2018-0398)	364	60.67
HUANG YC, 2016, INT J TOUR RES (https://doi.org/10.1002/jtr.2038)	355	39.44
CHUNG N, 2015, COMPUT HUM BEHAV (https://doi.org/10.1016/j.chb.2015.02.068)	355	35.50
JUNG T, 2015, TOURISM MANAGE (https://doi.org/10.1016/j.tourman.2015.02.013)	318	31.80
DIECK MCT, 2018, CURR ISSUES TOUR-a (https://doi.org/10.1080/13683500.2015.1070801)	277	39.57
HE ZY, 2018, TOURISM MANAGE (https://doi.org/10.1016/j.tourman.2018.03.003)	238	34.00
BOGICEVIC V, 2019, TOURISM MANAGE (https://doi.org/10.1016/j.tourman.2019.02.009)	236	32.71

In terms of most local cited documents, two articles stand out with 31 local citations, the already mentioned, "Exploring Consumer Behavior in Virtual Reality Tourism Using an Extended Stimulus-Organism-Response Model", and "Exploring the Implications of Virtual Reality Technology in Tourism Marketing: An Integrated Research Framework" [16], an article from 2015 published in the *International Journal of Tourism Research* in which is presented a study in a laboratory setting with 186 participants to understand how tourists would use a 3D virtual world.

4 Conclusions

Since the popularization of the XR technologies the focus has being mainly in the Industrial/Manufacturing and Health sectors, through direct improvements of currents process or indirectly like with 3D training simulators. However, in this paper we can see that Tourism is becoming one of the sectors being focused by researchers starting in 2017, with a significant increase of interest and production over the last years.

Between these researchers it highlights members of the Manchester Metropolitan University and the Kyung Hee University, which are also part of the pioneering countries, United Kingdom, and Korea, respectively, however the country with more scientific productions was identified as being China. These three countries also stand as the ones with more international collaborations and more significantly, with collaborations between themselves, being the principal researcher Dr. Timothy Jung (Jung T), which is a member of the Manchester Metropolitan University.

The principal journal in terms of quantity of articles is Sustainability, while the one with a bigger impact factor (by 2022) is Tourism Management, however, Current Issues in Tourism stands in the middle both in quantity of articles and in impact factor.

In terms of topics, the focus has been Social Sciences and Business/Economics, with particular concern with human acceptance and adaptation to the use of these technologies in Tourism, as well how beneficial they real are, both economically and for sustainable Tourism, as well for destinations marketing.

Relatively to future research, virtual tourism, metaverse and telepresence/authenticity seem to be the principal concerns for the next(s) year(s), however topics like heritage and marketing are still highly present.

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Digital Transformation in the Public Sector State of the Art in Local Government Bodies

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Abstract. With the aim of identifying whether local government bodies have integrated digital transformation procedures into their practices, as well as understanding their contributions, a literature review was carried out on research into digital transformation and local government. This review made it possible to identify that these bodies have been integrating procedures related to digital transformation, although still at an embryonic stage. The literature review also allowed us to recognize a set of contributions of digital transformation to local government bodies and to the well-being of local communities in multiple and varied aspects. Among these, within the scope of the digital urban development strategy (smart cities), in compliance with the SDGs of the United Nations 2030 Agenda, in collaborative work between organizations and in the implementation of support mechanisms for the elderly.

Keywords: Digitization · Local Government · Business Processes · Literature Review · Digital Transformation

1 Introduction

The objective of bodies associated with local government is to offer quality services to the community. The operational activities that are developed to guarantee the provision of quality services are normally organized into business processes. These business processes use various resources including the support of new information and communication technologies (ICT). The planned use of ICT, in support of business processes, will allow community members to access services provided by local government bodies via the Internet [1].

Local government bodies, in order to improve the provision of services they provide to the community, investing in ICT support, must review their business processes related to the provision of services with the aim of improving and adapting them to the use of the aforementioned technologies [1].

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There is no unified definition for digital transformation, which allows for multiple definitions of this concept. Therefore, this can be explained taking into account what the terms digital and transformation mean, associating the term digital with the use of ICT, while the term transformation is related to business processes [2].

Many government bodies have been strategically adopting Business Process Management (BPM) as a measure to improve their efficiency and responsiveness to the communities they serve. However, the implementation of BPM initiatives by local government bodies has posed many challenges, with many of these projects not being successful or not achieving the intended results [3].

A business process has associated actors and systems that interact with each other. Therefore, so that a business process can be analyzed and perceived, it is important to specify these entities [4]. Its identification is fundamental so that a strategy based on processes can be developed. This strategy consists of the integration of several activities that compete to achieve an objective. The identification of an organization's business processes leads to a process architecture, which represents the set of processes and their interrelationships. This architecture is crucial for defining the priorities and scope of process modeling and respective reengineering projects [5].

According to Roeding [6], the development of digital strategies, especially those developed for local government bodies, has not yet been sufficiently studied. There is research work carried out on digital strategies that shows their development and describes their implementation in local government bodies.

In view of what is presented above, this study aims to answer the following research questions (RQ):

RQ1: Have local government bodies been integrating procedures related to digital transformation into their practices?

RQ2: What are the contributions of digital transformation to local government bodies?

2 Related Work

The National Democratic Institute, a non-profit and non-partisan organization, works to support and strengthen democratic institutions around the world through citizen participation and accountability of government bodies. This institute published a guide [7] to help leaders of local government bodies reflect on the "why" of new technological approaches, the "what", what the needs of their citizens are and the "how" to successfully implement a project digital transformation.

If we add to the reflections of the leaders of local government bodies mentioned by the aforementioned institute the "where", the place where things happen, the "who", what resources are used and even the "when" things happen, we are faced with the well-known Zachman framework.

The Zachman framework is a tool that can help create knowledge and clarify doubts during the data analysis and decision-making process. It is, therefore, a strategic asset that can help shape organizational culture. Some of the benefits of its use include the following: (1) facilitating access to business process documentation; (2) facilitate the

integration of the organization's business processes holistically; (3) improve organizational performance by reducing the complexity of certain processes; (4) minimize the delivery time of organizational solutions with reduced development costs and maximize the reuse of organizational models; and (5) enable the creation and maintenance of a unified view of business processes and information technologies [8].

As supervisory authorities implement digital transformation projects without considering the need for their coordination, local government bodies continue to transform their information systems and business processes according to the frequency of changes suggested by those authorities. This situation creates a work overload for the workers of these organizations who must meet the demands that result from the constant updating of the various information systems [9].

In particular, activities related to accounting and accountability to citizens, within the scope of the local government's public service, are strongly impacted by the multiple facets resulting from the implementation of digital transformation processes carried out in an uncoordinated manner. Therefore, there is a need to explore more deeply the challenges that digital transformation poses from the perspective of accounting and accountability [10].

A study carried out by Mergel et al. [11], concluded that digital transformation is more comprehensive than the mere digitalization of business processes, and it is necessary to develop more research, considering not only the process and the impact of the transformation on these, but emphasizing the need for a holistic approach to implementing digital transformation processes.

Kuhlmann and Heuberger [12] developed a study that shows that the digital transformation carried out in local government bodies in Germany has faced important obstacles. Overall, they concluded that there are gaps in the ICT implementation process that result in a state of digital immaturity at the local government bodies level.

3 Methodology

The literature review was carried out using the framework proposed by vom Brocke et al. [13]. This framework suggests five steps to be followed: (1) define the focus of the literature review; (2) conceptualize the topic under analysis; (3) search for related literature; (4) summarize and analyze the literature collected and (5) systematize proposals for future work.

Thus, according to Cooper [14], in a first phase, the literature review will focus on digital transformation in local government bodies, with the aim of summarizing the conclusions obtained and providing a more comprehensive view of the digital transformation that has taken place in these organizations. In a second phase, the concept of digital transformation will be formed in local government bodies, focusing the analysis on the term "digital transformation" and the term "public government" or alternatively "municipality" or "municipal" or "municipalities" or "local authority". Once the concept is formed, the third phase must be developed in which databases and research keywords will be involved. In the fourth stage, after collecting enough literature on a topic, it has to be analyzed and synthesized. Finally, in the fifth phase, it is expected that the synthesis of the literature will result in a research agenda, composed of more precise and clarifying questions for future research.

Therefore, to assess the state of the art of digital transformation in local government bodies, a search was carried out in the following databases: b-on; EBSCO; Science direct; SCOPUS and Google Scholar, searching the title for the following terms: "digital transformation" and "public government" or "municipality" or "municipal" or "municipalities" or "local authority" written in English and published since 2012. In this research, 27 articles were considered, after duplications were rejected.

The year 2012 was taken as a reference, considering that the term "digital transformation" was coined in 2011 by Capgemini in partnership with the Massachusetts Institute of Technology (MIT). This partnership defined digital transformation as the use of technology to improve organizational performance [15].

4 Review Results

The digital transformation process is different for each local government body and is not always without flaws. Failures occur not only for technological reasons, but also for issues associated with business processes, people and organizational structures existing in each of the institutions in question. However, there is a need to harness the power of next-generation ICT to improve efficiency, cost-effectiveness and citizen service delivery. Even though the digital transformation process eliminates a number of physical requirements for interacting with local government bodies, these still have significant potential to improve services, especially where physical presence is mandatory. Although the overall impact of digital transformation on local government bodies is complex and multifaceted, it can improve the quality of and access to services provided by local government bodies; contribute to improving democratic accountability and citizens/users' trust in those institutions. Therefore, if used appropriately, within an adapted framework and aimed at achieving common objectives, new ICTs can have a positive impact on the provision of public services, improving the quality and efficiency of these services [16].

Lindgren et al. [17], using stakeholder theory, carried out an assessment of how stakeholders in local government bodies in Sweden interpret automation as part of the implementation of a digital transformation process and what their opinions are. About the expected results of this automation. These authors concluded that local government bodies are currently investigating and implementing ICTs that can automatically perform various administrative functions that were previously performed by administrative staff.

Weißmüller et al. [18], highlight, in their study carried out in Swiss local government bodies, that inter-organizational and inter-sectoral collaboration is one of the most promising strategies for successfully achieving the objective of any digital transformation process that takes place in local government bodies.

A study carried out in Sweden, by Norling et al. [19], aimed to contribute to research into the state of the art of digital transformation in local government bodies, seeking to answer the following research question: how digital transformation strategies are directed in local government bodies. This study concluded that the dominant direction of digital transformation strategies in local government bodies is centered on creating internal value and improving the efficiency of the activities carried out.

It is also necessary to highlight the importance that innovative and digital transformation actions developed by local government bodies have had in the context of meeting

the Sustainable Development Goals (SDGs), especially in the case of objectives number 8 (Decent Work and Economic Growth), number 9 (Industry, Innovation and Infrastructure), number 10 (Reducing Inequalities) and number 11 (Sustainable Cities and Communities) [20].

Continuous technological advancement, particularly with regard to ICT, has had an impact on the digital skills of citizens who increasingly demand quality digital services to the local government bodies. Consequently, local government bodies are pressured to implement digital transformation processes. However, their lack of resources, such as funds and qualified personnel, has prevented the success of their digital transformation. There are still not enough successful and sufficiently documented examples of digital transformation to assess the maturity of local government bodies with regard to digital transformation. This fact makes it more difficult for the management of local government bodies to create their own strategies for their digital transformation [21].

Also, a study carried out by Debeljak and Dečman [22], in Slovenia, brings a new dimension that can have an impact on the implementation of digital transformation programs in local government bodies, digital maturity. This dimension is one of the pillars that support the development and implementation of digital transformation programs that could enhance the capacity of these organizations to function as facilitators and/or providers of high-quality public services within the communities they serve.

Digital transformation in the public sector, particularly in local government bodies, can promote new ways of working, namely, as a facilitator of collaborative work between bodies [23–26], and involvement that build new models of service provision and create new forms of relationships between different stakeholders. There is still little empirical and systematic evidence on the digital transformation process in local government bodies, and the vast majority of existing studies focus on the digital transformation processes of the central government or the public sector as a whole. Local government bodies are an area that is still little explored and faces additional challenges [27].

Organizational capacity is important in the development of smart cities and therefore helps to successfully implement digital transformation processes through smart administration, urban collaboration and decision-making. Therefore, it must be assessed how local government bodies can improve their organizational capacity to successfully implement digital transformation processes [28].

The digital transformation in local government bodies will allow the integration of diverse data sources and the implementation of digital twins that can efficiently respond to citizens' needs and maintain the quality of the service offered by urban infrastructure [29], contributing to the dynamization of cities intelligent. It is important to be aware that digital transformation requires data and these will be collected and disseminated, through appropriate urban infrastructures, for the benefit of local populations.

The implementation of digital transformation programs and the development of well-being technologies can be an important pillar for the efficient functioning of municipal elderly care organizations (an increasingly relevant problem with the increase in life expectancy and the decrease in rates). Demographic). This situation presents us with Collingridge's dilemma: the impact of a wellness technology or digital service is difficult to predict until the wellness technology or digital service is widely developed and implemented in the intended way [29, 30].

Some studies also suggest that local government bodies in rural areas can take advantage of digital technologies to improve their communication, their provision of services and promote greater engagement with their communities. Investigating these topics contributes to the body of literature on digital communications in local governments and provides an agenda for other rural municipalities seeking to improve their communications strategies in the digital age [31, 32].

Some studies also suggest that local government bodies In response to growing financial, social and environmental pressures, local government bodies are increasingly turning to digital transformation and urban infrastructure management activities. Digital transformation can have a huge impact on the way local communities organize themselves and the way they carry out their activities, with processes constantly changing as technology evolves, in particular ICT [33, 34].

5 Conclusions

The literature review carried out allowed us to respond affirmatively to RQ1 - Have local government bodies been integrating procedures related to digital transformation into their practices? However, the implementation of digital transformation processes in local government bodies is still embryonic.

The literature review also allowed us to recognize a set of contributions of digital transformation, for local government bodies, as well as for the well-being of local communities in multiple and varied aspects, thus responding to RQ2 - What are the contributions of digital transformation to local government bodies? Among these contributions, the following can be highlighted.

Digital transformation, integrated into a digital urban development strategy (smart cities), with a true fusion of the main digital transformation strategies, including the integration of diverse data sources and adequate dissemination, can contribute to the quality of life of citizens and the management of urban infrastructures.

Digital transformation can contribute to achieving the United Nations 2030 Agenda, helping to achieve the SDGs. This agenda is broad and ambitious, addressing various dimensions of sustainable development (socio, economic, environmental) enhancing and promoting peace, justice and the functioning of efficient institutions.

Collaborative work between organizations is increasingly relevant so that organizations can take full advantage of the ubiquitous dimension of ICT in parallel with the Internet.

Low-density territories of which Portugal is a paradigm can benefit significantly from the implementation of digital transformation programs, for example, in terms of mechanisms that can be explored to guarantee the well-being of older populations and mechanisms that can be explored to ensure the healthy development of children and the retention of young adults.

In view of the aforementioned contributions, it is understood that, in order for local government bodies to be able to offer their citizens an efficient digital experience, based on the implementation of digital transformation processes, they need resources, both material and human (for example, urban infrastructure and qualified technicians). These

organizations must therefore implement ICT training programs so that their employees and citizens acquire the necessary digital skills.

Within the scope of implementing digital transformation processes, it can be seen that the presence of a digital leadership position; an entrepreneurial drive; and the speed of technological advances positively affect the quality of decision making and the efficiency with which organizations operate [35].

A limitation of the present work is the fact that the literature review is based on searching the keywords only in the paper title. A future development of this work would involve searching for the keywords also in the abstract and the papers' keywords.

Another future work, based on this work, it is proposed to carry out an exploratory study that allows evaluating the level of implementation of digital transformation processes in Portuguese municipalities.

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Hybrid Firefly-Grasshopper Optimisation Algorithm (FAGOA) for Optimizing Wireless Sensor Network Deployment

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Abstract. This research addresses the deployment challenge in Wireless Sensor Networks (WSNs) by introducing a novel hybrid metaheuristic algorithm that combines the Firefly Algorithm (FA) and the Grasshopper Optimization Algorithm (GOA). While FA has shown promise in solving technical problems, it suffers from slow convergence and limited local search capabilities, particularly in high-dimensional spaces. To mitigate these limitations, we propose the Firefly-Grasshopper Optimization Algorithm (FAGOA), which integrates the adaptive search dynamics of GOA to enhance FA's exploitation phase. Experimental results demonstrate that FAGOA significantly improves deployment efficiency in WSNs by optimizing parameters such as energy consumption and coverage overlap. Comparisons with state-of-the-art algorithms reveal FAGOA's superior performance.

Keywords: Deployment optimization · evolutionary algorithms · wireless sensor networks · energy efficiency · coverage · metaheuristics

1 Introduction

Effective deployment is crucial to achieving optimal performance in Wireless Sensor Networks (WSNs), which rely on spatially distributed sensors for environmental monitoring and data collection. While random deployment is suitable for inaccessible or hazardous terrains, it often leads to poor coverage and energy inefficiencies. Several nature-inspired optimization algorithms, such as the Bees Algorithm (BA), have been employed to enhance WSN performance. However, these methods typically suffer from shortcomings in large-scale scenarios due to weak exploitation strategies.

This paper proposes the Firefly-Grasshopper Optimization Algorithm (FAGOA), a hybrid approach that combines FA's global search abilities with GOA's local refinement strengths. By incorporating adaptive search mechanisms and multi-objective optimization, FAGOA seeks to maximize network coverage and minimize energy consumption, thereby extending the network's lifespan and reducing redundancy.

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2 Related Work

Previous efforts in WSN deployment optimization have explored various metaheuristics, including:

- **Improved Grey Wolf Optimizer (IGWO)**: Efficient in maximizing coverage but slow in convergence on larger problems.
- **Whale Optimization Algorithm (WOA)**: Fast but suffers from premature convergence.
- **Artificial Bee Colony (qABC)**: Effective but computationally intensive.
- **Maximal Coverage Hybrid Search Algorithm (MCHSA)**: Improves coverage at the expense of higher computing time.
- **Biogeography-Based Optimization (BBO)** and **Social Spider Optimization (SSO)**: Offer good coverage but lack mobility handling and scalability.

Most of these algorithms address either exploration or exploitation but not both. FAGOA overcomes this limitation by dynamically balancing both phases, improving scalability and solution diversity.

3 The Proposed FAGOA Algorithm

FAGOA combines FA and GOA to balance exploration (global search) and exploitation (local search). The hybrid structure allows fireflies to guide the search process while grasshoppers fine-tune promising solutions using social interaction models.

3.1 Algorithm Pseudocode

```
Start
  Initialize population of fireflies and grasshoppers
  Evaluate initial fitness
  While stopping criteria not met:
    Compute firefly brightness based on fitness
    Sort fireflies by brightness
    For each firefly:
      For each grasshopper:
        Compute distance and attraction
        Update grasshopper position (GOA rules)
      Update firefly position (FA rules)
    Apply crossover and mutation
    Recalculate fitness
    Update best solution
Return best solution
End
```

4 FAGOA Flowchart

The process flow includes:

1. Initialization of sensor positions
2. Fitness evaluation based on coverage, energy, and overlap
3. Iterative update using FA and GOA dynamics
4. Application of genetic operators (crossover/mutation)
5. Best solution tracking
6. Termination on convergence or iteration limit

5 Experimental Setup and Results

The proposed FAGOA was evaluated against four leading algorithms using metrics such as:

- **Coverage ratio**
- **Energy consumption**
- **Overlapping rate**
- **Computation time**

Key Findings:

- **Coverage**: FAGOA consistently achieved $> 95\%$ in complex terrains.
- **Energy**: Reduced consumption by ~ 20% compared to FA and GOA alone.
- **Overlap**: FAGOA minimized redundant sensing better than baseline methods.

6 Conclusion

This paper presented FAGOA, a hybrid algorithm tailored for optimizing WSN deployment. By leveraging FA's attraction model and GOA's social interaction mechanics, FAGOA offers a superior balance between exploration and exploitation. The results demonstrate its effectiveness in reducing energy use and maximizing coverage, outperforming other benchmark algorithms. Future work includes extending FAGOA to mobile sensor networks and dynamic environmental conditions.

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Work-in-Progress Traceability in Textile and Clothing Manufacturing: A Literature Review

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Abstract. Work in Progress (WIP) traceability in modern manufacturing encompasses statistical process control, Industry 4.0/5.0 integration, comparative studies on manufacturing strategies, and traceability systems, among other technologies, for continuous quality improvement. In this paper, we explore the state of the art in WIP traceability solutions for the Textile and Clothing (T&C) industrial sector, especially through the implementation of manufacturing traceability processes and computer-based multi-layered monitoring systems, integrating IoT and other technologies, such as Blockchain and Artificial Intelligence, to achieve different levels of digital transformation of industrial processes. We highlight some of the key aspects of manufacturing processes' WIP monitoring in T&C, identify critical unsolved aspects, and suggest future research directions to bridge the gaps.

Keywords: Work in Progress Traceability · Manufacturing Traceability · Industrial Internet of Things · Textile and Clothing

1 Introduction

In today's global and hyper-competitive marketplace, the Textile & Clothing (T&C) manufacturing sector faces several challenges. Manufacturers need to use the newest technologies and techniques to provide high-value, environmentally sound, and socially ethical products while responding to the customer's demands for transparency, sustainability, and personalization [1]. One of the most effective tools for this purpose is WIP traceability, which offers real-time visibility through the T&C production process from raw materials to finished garments.

The preliminary scientific research on WIP traceability in T&C has, thus far, explored the application of database traceability, computer-based multi-layered systems, statistical process control (SPC), Six Sigma methods, Industry 4.0 (I4.0) technological solutions, and agile techniques. Although these methods involve significant potential for data analysis, process control, and real-time visibility, the lack of comprehensive solutions in the

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T&C context suggests further thorough research. Thus, the present study will systematically review the current state-of-the-art on WIP traceability solutions for the T&C sector. By conducting this research, we aim to enhance the capabilities of WIP traceability solutions to meet the evolving needs of the T&C industry. Consequently, this can enable manufacturers to attain higher levels of productivity, openness, sustainability, and agility, guaranteeing their competitiveness and success in the global marketplace. This study aims to do a comprehensive analysis of the state-of-the-art in WIP traceability for T&C, identify critical components that are not fully addressed by present approaches, and propose future research directions to fill up these gaps.

The remainder of this paper is structured as follows: the next section covers the research methodology followed in this project. Section 3 reflects on the factory shop floor process in the T&C industrial sector. Section 4 presents a background review in Work in Progress (WIP) traceability processes (Sub-Sect. 4.1), and it also addresses digital maturity assessment frameworks (Subsect. 4.2) and discusses IoT architecture reference models (Subsect. 4.3). In Sect. 5 a discussion about the studied existing approaches to WIP traceability is conducted (Subsect. 5.1), using the Acatech I4.0 Maturity Index and the IoT frameworks discussed before, and some thoughts about technologies for WIP traceability in the T&C sector (Subsect. 5.2). Section 6 concludes the paper and presents some ideas for future work.

2 Methodology

For this literature review, the keywords “Process”, “WIP”, “Work In Progress”, “Manufacturing”, “Fashion”, “Textile”, “Clothing”, “Control”, “Evaluating”, “Assessment”, “Monitoring”, “Tracing”, and “Traceability” have been searched using the following indexed databases: Scopus, WoS, and Google Scholar, with the query: allintitle: (“Process” OR “WIP” OR “Work in Progress” OR “Manufacturing”) (“Fashion” OR “Textile” OR “Clothing”) (“Control” OR “Evaluating” OR “Assessment” OR “Monitoring” OR “Tracing” OR “Traceability”). The research was made in Nov./Dec. 2023, and the search criteria has been limited to 10 years, spanning from 2013 to 2023. The results obtained were 146 articles, which have been filtered by screening the title and abstract, removing all the ones that did not relate to T&C, resulting in 35 articles. These have been further filtered, removing the ones that were not related to WIP manufacturing traceability, and the seven resulting articles have been comprehensively analyzed.

3 Factory Shop Floor Process in the T&C Sector

From the creation of raw materials (like cotton, wool, polyester, etc.) to the creation of a final garment, many production activities are needed, such as spinning, weaving, dyeing, printing, and finishing, among others [2]. The T&C value chain is very large and involves many different types of industries [3]. Some industries perform a very specific production activity and carry out only one stage of the value chain of a T&C product. For example, some industries receive bales of cotton and produce yarn, others receive cotton yarn and produce fabric, etc. Others receive fabric and manufacture the pieces that are then sent for finishing at another company. Mainly to avoid transportation over

long distances, some industries carry out several of these stages in the same facilities. For example, the same industry can receive the yarn, produce the fabric, manufacture the parts, and do the finishing, all in the same facilities.

Figure 1 depicts a generic factory shop floor process in the T&C sector, using BPMN notation (Business Process Model and Notation). This diagram has been sketched after visiting a few T&C industries and represents both industries that carry out a specific manufacturing stage, or production activity, and those that carry out more than one stage.

As can be seen in the model, when a production order is issued, the first activity to execute is to identify the necessary raw materials, and if their needed quantity does not exist, it is necessary to create an order for each.

The process stops until the raw material is refilled (represented in the model by the timer event). Next, it is necessary to identify the machine (or machines) that will be used in production and load them. After that, it is necessary to check that everything is OK. To do this, usually, there is a checklist (represented by the data object in the BPMN model) that must be followed step by step. If something is not right, it must be alerted immediately so that the problem can be quickly solved. If everything is okay, then production can begin. The raw material quantity in stock must be updated. This is represented in the model by the outgoing arrow from the activity "select and load the machine" to the "products" data store. The machine must be constantly monitored so that, if something goes wrong, it can be reported as quickly as possible, solve the problem, and continue production. After the production activity is finished, it is necessary to report it, updating the product's stock information, as well as the production order state. At the end of a production activity, it is necessary to check the quality of the produced product. If the quality of the created product is not adequate, it must be discarded.

All this information must be properly recorded so that it can be used to improve process management. It should be noted that a product produced in a production stage, as a result of instantiating the described process, can be used as a raw material in the subsequent production stage. This is the reason why the "products" data store is the same at the beginning and at the end of the process.

In cases where several production stages are carried out in the same facilities, the process starts again, with the product produced in the current stage being used as raw material in the next production stage. In other cases, the products produced will be packaged and properly stored, and the information about the production order will be updated.

4 Background

This section explores the state of the art on WIP traceability processes and organizational digital maturity assessment, integrating insights from recent research articles. The main IoT Architectural Reference Models (ARMs) are also surveyed for identifying the main architectural layers, so that, in the Discussion's section, an attempt to identify each layer's components, for each state of the art study, is made.

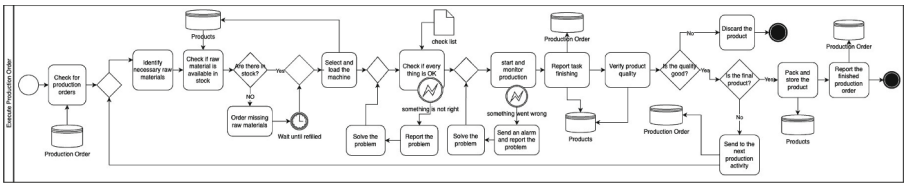

Fig. 1. Factory Shop Floor Process Model.

4.1 WIP Traceability Process

WIP traceability allows factory managers to track manufactured products or materials as they flow across the factory floor, as well as other information related to the materials used, such as parts provenance and current location in the factory, lot number, etc.. This allows, among other things, to forecast the required materials and respective quantities for each manufacturing order, and to forecast times and costs for completing these manufacturing orders, leading to improved efficiency of manufacturing processes.

The survey of works on WIP traceability in the T&C industries has identified four main categories of works, namely works that make use of Statistical Process Control (SPC) for monitoring WIP; approaches that integrate Internet of Things (IoT) and I4.0 technologies; studies that have compared manufacturing and process optimization strategies; and, works that have been based on innovative approaches and systems. These are presented in the next paragraphs.

Statistical Process Control (SPC). In [4], the proposed system employs control charts to monitor, analyze, and improve production processes. SPC ensures systematic process mapping, identification of critical product attributes, and proactive measures to prevent deviations, minimizing resource wastage and time. Similarly, in [5], the authors incorporated Six Sigma methodology in a medium-sized textile company, focusing on process monitoring for continuous quality improvement, using SPC charts. Control charts like Proportion chart (p-chart) and Xbar-R chart (XR-chart) are used to monitor the proportion of defective items and the process mean and variability over time. Also, tools for guided decision-making for defect elimination have been used.

Integration of Industry 4.0 (I4.0) Technologies. Marija Stanojeska, in [6], showcases how the integration of I4.0 technologies have revolutionized Work-In-Progress (WIP) traceability. Recent research in textile manufacturing showcases intelligent platforms for real-time data collection, enabling swift issues identification and correction, resulting in reduced non-conformities, efficient correction times, and cost savings. A pilot system for monitoring and tracking the manufacturing process has been put operational. The system gathers and processes data from each machine in the production line by having each operation being input into a controller. The data is saved in the monitor while the operator performs the operation on the machine. The operation on the machine is precisely coordinated with the data input into the controller. Through a fit-to-use software program, the data collected from each monitor provides real-time insights into completed tasks, stoppages, bottlenecks, delays, and deviations.

Manufacturing Strategies and Process Optimization. Authors in [7] conducted comparative analyses on manufacturing strategies, including Kanban, Constant Work in Progress (CONWIP), and Drum-Buffer-Rope (DBR), focusing manufacturing strategies for optimal productivity in a textile industry. Their objective was to offer valuable insights utilizing simulation tools like Promodel. The findings consistently highlighted Kanban's superiority, particularly in reducing WIP average cycle time and total cycle time. These results are in line with the goals of resource optimization and timely delivery.

Innovative Approaches and Systems. In the work presented in [8], the authors introduced Database Management Traceability Systems to address challenges in textile manufacturing, facilitating detailed tracking of processes, defects, and performance metrics. In [9], an innovative approach was introduced, Scrumban, which is a fusion of Scrum and Kanban, proved effective in dynamic manufacturing environments. Case studies in the T&C sector showcase Scrumban's adaptability, suggesting potential benefits across manufacturing domains. The authors in [10] introduced a computer-based multi-layered monitoring system for textile manufacturing processes, enhancing communication and information sharing, especially in handling errors.

4.2 Digital Maturity Assessment

Organizational digital maturity assessment, within the context of I4.0/5.0, employs the use of frameworks and models. Organizations can choose or adapt a model that best fits their specific needs, industry context, and strategic goals. One example of such an assessment framework is the Acatech I4.0 Maturity Index, as outlined in [11]. This comprehensive index serves as a valuable tool for discerning the current stage of organizations in their digital transformation toward becoming learning-oriented and agile entities. The Acatech I4.0 maturity index delineates six distinct stages, each representing a pivotal phase in the evolution of an organization's technological capabilities:

1. Computerization Stage: Focuses on leveraging computers and information technology for routine, repetitive tasks often performed in isolation.
2. Connectivity Stage: Marks the transition from isolation, replacing disparate information technology components with an interconnected system, fostering improved communication and collaboration.
3. Visibility Stage: Incorporates sensors to capture processes with a multitude of data points, enabling real-time tracking across the entire organizational landscape.
4. Transparency Stage: Centered around data analysis, this stage enhances decision-making by providing deeper insights and a clearer understanding of organizational processes.
5. Predictive Capacity Stage: Advances further by in- corporating predictive technologies to emulate future scenarios, allowing organizations to proactively plan and strategize.
6. Adaptability Stage: Culminates in the final stage, building on Predictive Capacity. It emphasizes continuous adaptation by integrating automated actions and decision-making into the organizational fabric.

Table 1. Reference Models' Comparison Table.

Reference Model	Year	Overview	Strengths	Weaknesses	Target Audience
IIRA	2015	IIoT integration	Well-defined layers, updated with emerging technologies	Specific to IIoT	IIoT architects, developers, implementers
IICF	2017	IIoT connectivity	Comprehensive approach to standards	More focused on standards than arch.	Network specialists & IIoT architects
OPC UA	2008	Machine-to-machine communication	Widely adopted, secure & reliable data exch.	Primarily communication protocol, less on arch.	Developers & integrators of industrial automation systems
RAMI 4.0	2015	Industry 4.0	Combines key Industry 4.0 elements, reference for standards	Primarily a conceptual model, less detailed on implementation	Industry 4.0 stakeholders, standards' organizations
ISO 42010	2011	Standardized arch. characterization	Promotes consistent architectural documentation	Generic framework, may require adaptations	Architects & engineers across various domains

Table 2. A summary of the reviewed articles (Note: N.A/N.S - Not Applicable/Not Specified).

Ref.	Publication Year	Maturity Level	Edge/IoT Technologies	Fog/Communication Techonologies	Cloud/Application Technologies	Methodology
[4]	2021	5	Sensors	N.A./N.S.	N.A./N.S.	Statistical Process Control
[5]	2013	2	N.A./N.S.	N.A./N.S.	N.A./N.S.	Statistical Process Control
[6]	2022	5	Sensors, Controllers and Digital Platforms	N.A./N.S.	fit-to-use software	Industry 4.0
[7]	2018	5	N.A./N.S.	N.A./N.S.	N.A./N.S.	Kanban, Conwip, DBR
[8]	2018	4	N.A./N.S.	N.A./N.S.	Prototype with Microsoft Access	Database traceability
[9]	2016	2	N.A./N.S.	N.A./N.S.	N.A./N.S.	Scrumban
[10]	2021	2	N.A./N.S.	N.A./N.S.	Prototype with PHP, MySQL, Apache	Computer-based multi-layer

4.3 IoT Architectural Reference Models

IoT ARMs serve as blueprints for structuring and modeling industrial computing paradigms, complementing digital maturity assessments. While the Acatech index focuses on overall digital maturity, ARMs provide specific guidance on designing and implementing technology infrastructure. Table 1 presents a comparison between the ARMs reviewed in this article, highlighting their strengths and weaknesses.

The Industrial Internet Reference Architecture (IIRA) was developed in [12], by the Industrial Internet Consortium (IIC) in 2015. With an emphasis on the Industrial Internet of Things (IIoT), this framework guides the integration of digital and physical components. The IIoT deployment process is made more structured by the IIRA, which outlines the main architectural elements, such as edge devices, connection, data processing, analytics, and security layers. In 2022, the IIC refined the 2015 IIRA version [13], adding new technologies, concepts, and emerging technologies in IIoT. An extensive approach for incorporating connectivity standards into IIoT architectures, Industrial Internet Connectivity Framework (IICF) was presented by the IIC in a 2017 publication [14]. The suggested tiered approach, which includes physical, link, network, transport, framework, distributed data interoperability, and management levels, is comparable to the OSI Network model. The Open Platform Communications Unified Architecture (OPC UA) [15], which was released in 2008, is a machine-to-machine communication protocol widely used in industrial automation. OPC-UA provides standards and specifications for interoperability and data exchange in industrial environments and facilitates secure and reliable data exchange between devices and systems, making it a crucial component in modern industrial architectures. Similar to IIRA, this protocol has changed throughout the years to accommodate changing industry standards. The most recent version, 1.04, was made available in 2017. The Reference Architectural Model Industrie 4.0 (RAMI 4.0) was released in 2015 by Zvei, an electrical German firm. It combines all of the key elements of I4.0 into a three-dimensional layer model [16]. RAMI 4.0 can act as a reference for coordinating national and international standards with the requirements of various sectors. Finally, the ISO 42010 standard [17], published in 2011 by the Institute of Electrical and Electronics Engineers (IEEE), offers a framework for uniformly and standardly characterizing systems architecture, including its elements, relationships, and interactions. One of the significant advantages of this framework is its ability to promote consistent and structured documentation of architecture across various domains and industries.

5 Discussion

5.1 Analysis of Previous Approaches to WIP Traceability

The principles embedded in the Acatech I4.0 maturity index [11], explained in Sect. 4.2, have been systematically applied to analyze and categorize the findings derived from each of the articles reviewed in Sect. 4.1. For the maturity level identification of the reviewed articles, each one of them has been analyzed, and the requirements for each maturity stage have been verified within the technologies and methodologies stated to be used in the article. Table 2, presents a summary of the reviewed articles with the

technologies and methodologies used in each article, justifying the assigned maturity stages.

Within the works examined, several maturity stages are observable. In Stage 2 (Connectivity Stage), initiatives such as integrating Six Sigma methodologies [5] or adopting SCRUMBAN [9] for production planning in luxury and fashion manufacturing highlight systematic improvements and enhanced collaboration. However, while [10] enhances collaboration and communication, the absence of explicit emphasis on predictive technologies situates it within this stage. Moving to Stage 4 (Transparency Stage), in [8] the authors propose a comprehensive traceability system, addressing the challenges faced by T&C manufacturing sector. Finally, in Stage 5 (Predictive Capacity Stage), works like [4] employ control charts and integrate artificial intelligence for predictive manufacturing process management, while [6] implements Industry 4.0 techniques for process monitoring and quality control, and [7] leverages simulation tools to compare and analyze manufacturing strategies, illustrating advanced predictive technologies for the emulation of future scenarios.

In Table 2, three architectural layers have been considered for the identification of technology components of each surveyed work. These layers, namely Edge/IoT Technologies, Fog/Communication Technologies, and Cloud/Application Technologies, have resulted from abstracting and trying to converge the several models from the studied ARMs.

There are several industry-wide reference models for industrial IoT architecture, but the acceptance of these models is not always certain. Opting for custom-made architectural solutions often arises from the necessity to address specific operational limitations and demands. Custom architecture would be the best option if legacy systems require a customized method of interaction. To ensure uninterrupted operations and minimize downtime, industrial processes often require excellent performance, dependability, and accessibility. Furthermore, there are difficulties managing data security and privacy in these kinds of settings. Enforcing strict safety procedures and putting in place extensive security measures via a tailored architecture makes sense, protecting the confidentiality and integrity of critical data.

5.2 Technologies for WIP Traceability in the T&C Sector

With the articles reviewed in Sect. 4.1, and further analyzed in the previous subsection, it has been concluded that there is a need for real-time visibility of the process, which would allow the industry to understand the location and status of the relevant materials through the production process, optimizing the production flow and identifying bottlenecks. Traceability should also be transparent, enabling it to track raw materials, production steps, and quality steps.

One very important piece to add to T&C is the early defect identification and correlation mechanism, which would minimize waste and rework costs. There is also a need to add an improved decision-making mechanism that facilitates data-driven decision-making for resource allocation, inventory management, and production planning. Finally, there is a need for supply chain collaboration because integrating the suppliers into the traceability domain ensures ethical sourcing practices and efficient material flow.

The reviewed approaches address various aspects of T&C needs, but with varying degrees of applicability, starting with the SPC, which can be applied to process monitoring and defect identification. There are I4.0 technologies that are applicable for real-time visibility, data collection, and analysis. There are management techniques like Kanban and ScrumBan which provide flexibility and adaptability for dynamic environments. There are also multi-layered monitoring systems, which improve communication and information sharing. However, there are some limitations to it: first, there is an integration challenge, because integrating diverse technologies and data sources across the supply chain can be complex; second, there are security and privacy concerns, as protecting sensitive data related to production processes might require robust and secure measures. There are also some aspects that weren't covered by the state-of-the-art approaches. Traceability should also be implemented for tracking the origin and processing of the materials to ensure sustainable practices and ethical sourcing throughout the supply chain. In the articles, defect identification is mentioned, but proactive measures to prevent defects through the production stages should be implemented, and finally, there is a need to integrate human expertise with advanced analytics for more informed decision-making.

6 Conclusion and Future Work

This study overviews work-in-progress (WIP) traceability mechanisms in the context of the textile and clothing (T&C) industry. While the reviewed approaches offer valuable solutions for real-time visibility, data analysis, and process monitoring, critical aspects specific to T&C remain unaddressed. The key features that were lacking in the existing approaches, are mainly related to:

- Problems with integration impede the supply chain's and separate systems' smooth data flow.
- Essential aspects like sustainability, proactive quality control, and personalization.
- Human-machine collaboration is not fully covered.

Future work could also be done to improve the T&C manufacturing industry:

- Proactive quality control, defect prediction, and predictive maintenance can be achieved through the design and application of AI-powered models that use real-time data.
- Integration with traceability solutions for sustainable sourcing practices, tracking material provenance, processing methods, and environmental impact throughout the value chain.
- Foster research on collaborative systems that combine human expertise with advanced analytics for informed decision-making and process optimization.

With solutions for these proposed research topics, the T&C industry can leverage WIP traceability to achieve higher levels of efficiency, transparency, sustainability, and responsiveness, ensuring its continued growth and competitiveness in the global market.

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Innovative Mosquito Breeding Site Detection
Leveraging YOLOv7 with Transformer Technology

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Abstract. Managing mosquito breeding grounds is a significant global public health issue. In this case, using drones in conjunction with automatic image detection is a viable tool. However, the task faces significant challenges due to the varying altitudes at which drones operate, leading to substantial variations in object scale that hinder network optimization. Furthermore, high-speed flight and low-altitude manoeuvres introduce motion blur, making object distinction even more challenging. We propose an enhanced approach to tackle these issues by integrating a Transformer Prediction Head into the YOLOv7 framework (specifically, the Swin Transformer) using pre-trained weights from the VISDRONE dataset. We conducted extensive experiments using the Mosquito Breeding Grounds (MBG) Database, which was pre-processed and augmented. The proposed method demonstrates remarkable performance and interpretability in drone-captured scenarios. The average precision (AP) result of YOLOv7 across all classes is 88.4%, with particularly notable performance in the bucket and water tank classes, achieving a mAP@.5 of 96.9%. The results suggest that YOLOv7 with Transformer Prediction Head can be used to automate the detection of mosquito breeding grounds.

Keywords: aerial images · object-detection · deep learning · mosquito breeding grounds · YOLOv7

1 Introduction

The threat of mosquito-borne diseases, particularly in tropical and subtropical regions like Brazil, is a significant public health concern [10,11]. The built environment, including stagnant water in unoccupied properties, is crucial in creating breeding grounds for mosquitoes [10]. Land use change, such as urban sprawl and

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deforestation, also contributes to the proliferation of mosquito habitats [13]. A multi-faceted approach is needed to address these issues, including improving the built environment, responsible land use, and innovative biological control measures [10,12,13]. These measures can significantly contribute to mosquito control and disease prevention, ultimately reducing the burden of mosquito-borne diseases on public health. We can effectively contribute to mosquito control and disease prevention by addressing these specific habitats [14].

The advancement and sophistication of Unmanned Aerial Vehicles (UAVs) have revolutionized the speed and cost efficiency of detecting pools and water tanks, marking a significant improvement over methodologies from a decade ago [6]. Despite this progress, numerically quantifying puddles from the voluminous data generated during aerial surveys remains labor-intensive, traditionally relying on manual methods. UAVs have become increasingly valuable for environmental monitoring, celebrated for their high spatial resolution, cost-effectiveness, and adaptable flight scheduling capabilities [5,19,23].

In public health initiatives, UAVs offer a promising solution to bridge the observational gap between on-the-ground data collection and remote sensing technologies. They deliver unparalleled spatial detail across extensive areas, combining efficiency with economic feasibility [1]. However, the deployment of drones in populated regions faces limitations due to safety and privacy concerns, highlighting the need for regulatory frameworks and technological advancements to mitigate these issues [19]. Additionally, UAVs can cover a large area relatively quickly, reducing the need for manual inspections. According to [21], combining UAVs with artificial intelligence techniques, such as deep learning, can develop efficient and cost-effective approaches for road damage detection. It is frequently mentioned as being utilized for urban inspections of things like swimming pools [3], rooftops [8], vegetation [15], and urban environments [4,20].

The aerial image dataset presents several challenges, including densely packed targets, a significant presence of small objects, and instances of severe occlusion in certain scenes. These factors make it challenging to extract apparent object features, and the object detection box characteristics in the dataset significantly differ from those in the pre-training dataset. Consequently, achieving optimal results using a conventional object detection algorithm becomes challenging.

To address this issue, we propose a network structure optimization tailored explicitly for small objects. In this work, we redesign the size of the detection head to enhance the input of characteristic information to the detection head. Additionally, we increase the number and density of anchor frames to improve the network's ability to perceive small objects effectively. These modifications aim to overcome the limitations of the aerial image dataset and improve the detection performance for small objects, [25,27].

Our contributions are as follows:

- We introduce an additional prediction head to handle large-scale object detection, allowing the model to adapt better to object size variations.
- We incorporated the Transformer Prediction Heads into YOLOv7.

– We train the model from a pre-trained model with the VISDRONE dataset [26]

2 Related Work

Object detection tasks heavily rely on deep neural network (DNN) based models, which can be categorized into distinct types based on various criteria. One key criterion is whether the model generates candidate boxes before detection, dividing models into one-stage and two-stage detectors. The YOLO (You Only Look Once) series has emerged as one of the most widely used algorithms for object detection. Over time, multiple versions of YOLO have been released, each with significant improvements in detection time. YOLOv3 and YOLOv4, in particular, have made substantial advancements in deep learning-based object detection. YOLOv4 has been optimized for real-time detection, trained on extensive image and video datasets, and incorporates techniques like Mosaic data augmentation and DropBlock to enhance performance.

Object detection in images captured by UAVs presents distinct characteristics compared to traditional object detection scenarios. First, the shapes and sizes of the detected objects vary considerably in these images. Moreover, it is common to find many objects that can be detected in UAV scenarios.

The progression of the YOLO (You Only Look Once) framework for object detection in UAV imagery has marked substantial progress. Samyal et al. [18] tailored YOLOv4 to enhance its accuracy and real-time detection capabilities, focusing on the challenges posed by truncated and occluded objects. Gunawan [7] evaluated the efficacy of different YOLO versions, finding YOLOv5s to offer satisfactory precision coupled with impressive processing speeds. Sahin et al. [16] pioneered YOLODrone, an iteration that surpasses YOLOv3 by specializing in object detection within drone-captured images. Building upon this, the same team introduced YOLODrone+ in a subsequent study [17], further refines the architecture by integrating additional detection layers and leveraging transformer models to boost accuracy. The repetition of the introduction of YOLODrone appears to be an oversight; however, the essence captured is the iterative enhancement of YOLO architectures, showcasing their growing efficiency in UAV-based object detection tasks. This work collectively underscores the dynamic improvement and applicability of YOLO algorithms for UAV image analysis.

This peculiarity brings additional challenges, mainly due to the computational resource limitations of UAVs. As a result, the progress achieved in object detection in generic scenarios, such as PASCAL VOC and COCO, has not yet been fully replicated in object detection in UAV imagery. Several studies have focused on small object detection, mainly using progressive structure approaches such as Peele, ClutDet [24], and DMNet [9]. In work [2,28], a method was developed to address these challenges by adding a prediction head to the already existing heads in YOLOv5. It is worth noting that all prediction heads are

transform-based. Another method called M-CenterNet, which uses multiple center points, has also been suggested to handle objects of minimal dimensions in aerial footage [22].

3 Proposed Architecture

The architecture builds upon the YOLOv7 algorithm and incorporates several enhancements to improve object detection accuracy and performance.

The proposed architecture includes the integration of Transformer Prediction Heads (TPH) into the YOLOv7 framework. The TPH introduces a multi-head prediction mechanism based on transformer models[27], which allows for more accurate localization of objects in high-density scenes. By leveraging the power of transformers, the model can capture long-range dependencies and semantic relationships between objects, leading to improved detection performance, as described in [21].

Additionally, the proposed architecture integrates the Channel Attention Module (CBAM) into the YOLOv7 network. The CBAM module enhances the model's ability to identify regions of interest in images with extensive coverage. By adaptively recalibrating channel-wise features, the CBAM module effectively highlights relevant object features, improving detection accuracy and reducing false positives.

In our experiments with YOLOv7 and the Transformer Prediction Head, we integrated the transformer architecture as the prediction head within the YOLOv7 model, replacing the conventional CNN-based prediction head. By utilizing the features extracted by the YOLOv7 backbone network, the transformer head produces predictions for both object locations and class probabilities. Figure 1 illustrates the YOLOv7 + Transformer Prediction Head model.

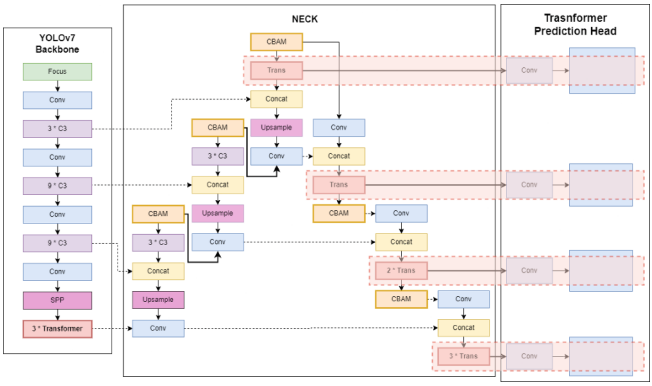

Fig. 1. YOLOv7 + Transformer Prediction Head model.

The proposed architecture, along with the code implementation, is available at https://github.com/luisaugustos/YOLOv7-MBG. The repository pro-

vides access to the source code, dataset, and instructions for reproducing the experiments and training the model.

4 Dataset and Parameter Settings

The Mosquito Breeding Grounds (MBG) is a database of annotated videos specifically created to detect possible *Aedes aegypti* mosquito breeding sites in aerial videos captured by drones. These videos were taken using an unmanned aerial vehicle with a high-definition camera. The MBG database has annotations of bounding boxes covering various objects of interest, such as bottles, buckets, pools, puddles, tires, and water tanks.

The image database consists of 13 videos, which were processed and transformed into individual images (frames). Due to the large amount of videos we have selected only the videos 2, 6, 9, and 12 for training, resulting in 5,094 images. Of these images, 4,488 were used for training, 404 for validation, and 202 for testing. This strategic selection allowed us to obtain a diverse and representative set for training and evaluating the detection model. The images have been resized from 3840×2160 to 1536×864 in the first training process and 640×640 in the second process. The augmentation process is used with the following settings:

The pre-processed dataset is available at Roboflow[1].

- Outputs per training example: 2
- Bounding Box Rotation: Between $-15°$ and $+15°$
- Bounding Box Shear: $\pm 15°$ Horizontal, $\pm 15°$ Vertical

The experimental setup for this study used Ubuntu 18.04 as the operating system, with a total memory of 128 GB. The GPU used was an RTX3090. CUDA version 11.02 was installed, and the experiments were conducted using Python 3.7.

During the training process, a batch size 16 was used, and the Adam algorithm was employed to update the gradients. The initial learning rate was set to 0.01, and the number of epochs for training decreased by ten at specific intervals. A momentum value of 0.9 was utilized in the training process.

5 Results

The model's training for mosquito outbreak detection lasted approximately 6 h, following the settings mentioned in Sect. 4. This training resulted in an overall mAP of 88.4% for all classes. However, this value was slightly lower due to the "bottle" class, which consists of objects too small to be detected with aerial images. On the other hand, the other classes obtained significant results, demonstrating the model's effectiveness in detecting the respective objects.

[1] https://universe.roboflow.com/luis-augusto-silva-bq4bv/mosquito-suh0p/dataset/1.

In Table 1, we can observe that the performance varies across different classes. For the class "all," the precision is 0.937, the recall is 0.842, and the mAP@.5 is 0.884. Notably, the "bucket" and "water tanks" classes demonstrate high precision, recall, and mAP@.5 scores, indicating accurate and consistent detection performance for these categories.

Table 1. Validation Results

Class	Images	Labels	P	R	mAP@.5
all	404	1229	0.937	0.842	0.884
bottle	404	101	0.841	0.525	0.58
bucket	404	161	0.974	0.924	0.969
pool	404	116	0.943	0.879	0.924
puddle	404	25	0.926	0.96	0.949
tire	404	189	0.958	0.837	0.914
water tanks	404	637	0.978	0.925	0.969

On the other hand, the "bottle" class has relatively lower precision, recall, and mAP@.5 scores than other classes. Similarly, the "puddle" class exhibits lower precision but achieves a high recall and mAP@.5 score. These differences highlight variations in the model's ability to detect different objects accurately.

Figure 2 illustrates the confusion matrix diagrams comparing the performance of the improved YOLOv7 version. In the confusion matrix, each row represents an actual class, while each column represents a predicted class.

Our proposed method exhibits comparable detection precision when analyzing pools, buckets, puddles, water tanks, and tires. Moreover, we observe significantly higher detection accuracy compared to YOLOv7. Furthermore, it is worth noting that the confidence scores for the "bottle" class are relatively lower, as depicted in the confidence graph on Fig. 3. This can be attributed to the smaller dimensions of the bottles compared to other objects in the detection scenarios.

This algorithm is a state-of-the-art algorithm that enhances and upscales images to improve the robustness and accuracy of the model. However, as seen in Fig. 4, several issues with the default parameters negatively impact the results.

Using these techniques, YOLOv7 can increase the size and diversity of the training dataset. This can help prevent overfitting and improve the model's generalization ability.

The proposed algorithm's visual effects on various aerial image detection scenarios were evaluated using images selected from the MBG test set. These images were chosen to represent complex scenarios and object occlusion conditions. The results obtained from the evaluation are shown in Fig. 5. In addition, a color similarity was observed between the "pool" and "water tank" objects.

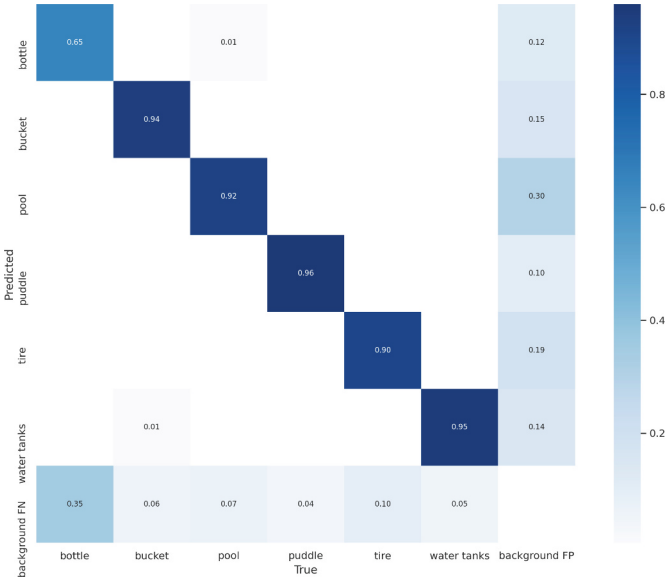

Fig. 2. Confusion matrix of test results.

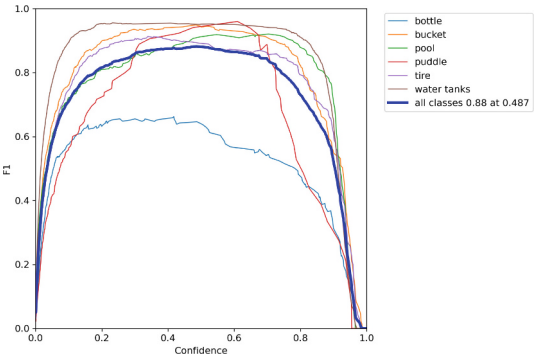

Fig. 3. F1 Curve.

Overall, these findings validate the suitability of our method for automated detection of mosquito breeding grounds and other applications requiring accurate object detection in aerial images. The proposed algorithm's performance surpasses that of YOLOv7, further emphasizing its potential in advancing aerial image analysis.

Fig. 4. Image augmentation process.

Fig. 5. Test images results.

6 Conclusion

In conclusion, this work addressed the challenge of detecting possible Aedes aegypti breeding sites in aerial images captured by drones. Improvements were

made to the YOLOv7 algorithm, such as adding a Transformer Prediction Heads-based prediction head and integrating the CBAM method. These modifications significantly improved object detection in high-density scenarios and images with extensive region coverage.

The conducted ablation experiments prove that the implemented modules enhance object detection accuracy and effectively showcase the detection results in various scenarios. These experiments validate the suitability of YOLOv7 for object detection in UAV aerial images of mosquito breeding grounds.

Experimental results demonstrate the effectiveness of the proposed architecture in detecting potential breeding sites in aerial images. The overall mean Average Precision (mAP) for all classes achieved an impressive score of 88.4%. While the detection precision for most classes was significantly high, the bottle class presented some challenges due to its small size, resulting in slightly lower accuracy.

Based on the obtained results, the improved YOLOv7 model is an effective and competitive solution for the automated detection of potential mosquito breeding grounds in drone-captured scenarios. This approach can potentially assist in preventing and controlling mosquito-borne diseases by providing an accurate and reliable tool for identifying mosquito breeding-prone areas and implementing appropriate control measures.

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Cosmic Observatory, a Virtual Reality Game to Promote Computational Thinking

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Abstract. The use of games to promote Computational Thinking (CT) is a popular approach, acknowledged for its well-established and significant benefits. On the other hand, the impact of Virtual Reality (VR) on motivation is fully documented in the educational literature. The aim of the project here reported is to combine VR with gaming to build an effective Learning Resource (LR) to develop CT skills in young people. Our objective is to create an engaging VR game, called Cosmic Observatory, that can be played without special glasses - accessible on desktop or non-immersive Virtual Reality devices. The effects concerning the reality virtualization will be created using the web interface. Cosmic Observatory challenges to develop CT skills, namely *pattern recognition* abilities, are described. The game architecture is also discussed.

Keywords: Computational Thinking · Virtual Reality · Learning Resources · Game-based Learning

1 Introduction

To program a computer, aiming at solving a problem, is an hard task that requires from the human being (the programmer) many demanding abilities. *Statement analysis and Abstraction, Problem decomposition, Pattern recognition, Deductive or Inductive reasoning, Instruction ordering (or Algorithmic reasoning)*, among others, are the most relevant skills that have to be developed. Some individuals born with one or more of those capabilities, but most of the times they must be trained. Crucial attitudes for problem solving, such as *perseverance, planning, debugging, adaptation, optimization, creation, tinkering, collaboration*, also have to be promoted. Nowadays those skills and practices, considered to be crucial to learn easily matters as Computer Programming (CP), are coined, after

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the seminal work carried on by Jeannette Wing [11], Computational Thinking (CT).

To develop on children such a collection of skills and practices, specialized analogical or digital resources are commonly used. The need to improve permanently the referred competences to become a good problem solver, and consequently a competent programmer, impelled the necessity to create new and more motivating Learning Resources (LR) capable of helping young pupils to acquire and perfect those abilities and attitudes.

In that context, we intend to discuss in this paper the design and implementation of a modern LR, *Cosmic Observatory*, to promote CT on young people. *Cosmic Observatory* is a game that explores the potential of Virtual Reality (VR) to enhance the engagement of pupils. The VR-based motivation will lead young people to play the game until completion, developing skills as logic reasoning, abstraction, and pattern recognition. Analysis, planning, persistence will also be trained.

The paper is organized as follows. Section 2 is an introduction to Computational Thinking, chief concepts and relevance in our XXI century. Section 3 presents the main characteristics of Virtual Reality to support the technological chosen approach. Section 4 offers a short description of *Cosmic Observatory*, the game under development, and discusses its architecture. Section 5 presents the game overview, the narrative, its mechanics, and the challenges that composed *Cosmic Observatory*. Section 6 closes the paper, summarising the proposal and the main ideas presented, and providing guidelines for future work.

2 Computational Thinking

This section is intended to provide the basic notions about Computational Thinking (CT) and its connections with Computer Programming (CP) to help the Reader on understanding deeply the Object that is trained by the game that we discuss along the paper and which is under work.

CT is essential for anyone wishing to learn CP, but it is not exclusive to it. This way of thinking helps people to look at problems objectively rather than emotionally, so they can solve them more easily. This is because the concept of CT is characterized by a set of capabilities and attitudes considered by the Computer Science community of utmost importance for solving simple to hard problems [12], involving big data structures (to hold the entities present in the domain and their relationships) as well as requiring complex algorithms. According to Wing [11], acquiring such a thinking style should be a fundamental aim, just like getting the ability to speak, read, or write, given that it is crucially good for all people, not just computer scientists. Actually, the set of skills and practices that characterize CT enable effective and efficient problem-solving, predisposed to be executed by computers.

As said above, the skills that make up CT include capacities such as: logic reasoning (doing deduction, induction, or abduction to get new knowledge from given facts [2,3,5]); providing step-by-step ordered instructions (the ability to

organize a set of instructions to correctly perform a task usually known as algorithmic thinking [2,5,8]); decomposition (the ability to break down a problem into less complex steps to reduce difficulty [2,5,8]); problem analysis and abstraction (the ability to comprehend the different elements of a problem [1,3] and to identify what is relevant ignoring unnecessary details [2,5,8]); solution evaluation (ensuring that the solution is adequate to solve the problem by checking limit cases [2,5,8]); and pattern recognition (the capacity to identify similarities or recognize patterns between problems and resolve them based on previously defined conclusions [2,5]).

These skills are supported and enhanced by practices or attitudes that are essential dimensions of CT, such as collaboration (teamwork) [2,5]; perseverance (continuity and persistence, even in the face of more complex problems) [2,5]; debugging (identification and correction of errors) [2]; experimentation (alteration and observation of results - cause and effect experiments) [2]; creation (design and execution with creativity) [2]; planning (definition of long-term objectives and strategies to achieve them) [3]; optimization (restructuring for a more efficient solution) [1,3]; and adaptation (adjustment of strategy/resolution to each situation) [1,3].

3 Virtual Reality

To understand Virtual Reality (VR), it is essential to know how it began. The roots of VR can be traced back to the mid-20th century, when Ivan Sutherland and Daniel Evans developed the first head-mounted display system, known as the "Sword of Damocles" (see Fig. 1) [10]. In 1965, Ivan Sutherland introduced the idea of making the virtual world look, sound, feel, and respond realistically to the viewer's actions [9].

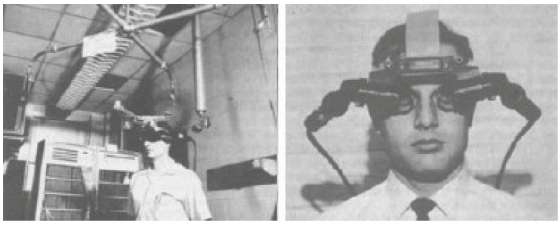

Fig. 1. Sword of Damocles [10].

VR constitutes a wholly digital, computer-generated, three-dimensional experiential realm, where immersion, presence, and interactivity are the primary roles [6]. In contrast to conventional user interfaces, which merely permit users to observe a screen, VR grants users the ability to enter an experience, becoming fully immersed in and engaging with a three-dimensional environment.

VR simulations can be broadly categorized into three primary types: non-immersive, semi-immersive, and fully-immersive[1]. *Non-immersive* can generate a computer-simulated environment while enabling the user to remain cognizant of their physical surroundings. *Semi-Immersive* provides users with a sense of an alternative reality when they engage with digital imagery, while still maintaining their connection to the physical world. It is often used in training applications that rely on high-resolution displays, powerful computing systems, or projectors [6]. *Fully immersive* simulations deliver the most authentic simulation encounter, encompassing both visual and auditory aspects. To engage with and interact within fully immersive, users necessitate appropriate VR glasses or a Head-mounted Display (HMD). VR headsets offer high-resolution content and an expansive field of vision. The display typically divides into each eye, engendering a stereoscopic 3D effect, which, when combined with input tracking, forges a full immersive and credible experience.

VR has traditionally found widespread adoption in gaming and entertainment, but its utilization appears in various other domains, notably education. Actually, the applications of VR are almost endless [6].

3.1 Immersion

According to [6], there are six types of immersion: tactical, strategic, narrative, spatial, psychological, and sensory.

Tactical Immersion is the sense of complete engagement within a virtual environment while performing tactile operations that demand skill, creating a state where players feel "in the zone" and achieve success through refined actions.

Strategic Immersion involves intellectual engagement, where individuals face mental challenges and decision-making, as seen in scenarios like chess, where players must select the correct solution from a multitude of possibilities.

Narrative Immersion occurs when players deeply invest themselves in a story, comparable to the immersive experience of reading a book or watching a movie.

Spatial Immersion is experienced when a player perceives the simulated world as convincingly real, feeling genuinely present within the virtual environment.

Psychological Immersion occurs when a player confuses the game with real life, blurring the boundaries between the virtual and reality.

Sensory Immersion involves a unity of time and space, where the player fuses with the image medium, influencing impressions and awareness in the virtual environment.

[1] https://heizenrader.com/the-3-types-of-virtual-reality/.

4 Cosmic Observatory, the Architecture

Taking into account the project objectives, identifying the abilities and attitudes that characterize CT, and understanding the diverse ways to build games resorting to VR techniques, it was possible to design and plan the development of the Cosmic Observatory game. This section describes the architecture that will drive the game development.

The architecture described in Fig. 2 represents an interactive system designed to provide an immersive and adaptive gaming experience. At the center of this system is the *Game Engine*, the brain behind the game operation, which receives inputs from the *Player* and the necessary contextual information from the *Game Database*.

As the *Player* interacts with the game, his progress is stored in the *User Database*. This data storage allows the player to recover the previous state, thus ensuring a fluid continuity of the gaming experience. The flow of information between the modules *Recover State* and *Game Engine* ensures that the game is aware of the *Player's* actions and progress.

The processing of data by the *Game Engine* is vital for the evaluation of the *Player's* performance, carried out by the *Evaluation Module*. This module not only gives the player a score, but also provides specific feedback on their actions and strategies. These evaluations are then stored in the *User Database*, thus building up a detailed profile of the *Player*.

In addition, the system includes a *Feedback Module*, which is responsible for sending information about the player's performance to the game. The latter acts as a central point for broad analyses, aggregated statistics, and insights into game patterns. The feedback is then generated and returned to the *Player*, thus enriching their understanding of their own performance and encouraging improvements.

Cosmic Observatory not only returns feedback to the *Player*, but also displays visual data provided by the *Game Engine*, creating an immersive gaming experience.

In short, this architecture not only allows interaction between the *Player* and the game, but also collects data, evaluates performance, provides feedback, and enriches the gaming experience. By integrating elements such as databases, evaluation modules, and feedback, this architecture creates a robust ecosystem that aims to continually improve the user experience in the game.

A simplified version of the system class diagram, depicting the main classes, their attributes, and the relationships interconnecting them, is illustrated in Fig. 3.

Each player (*userData*) has, at least, attributes such as *user-id*, *password* and an *user name*. Along the time, while playing the game, the player makes progress and attains a new status or position that is described by a set of attributes which must be stored from one session to another. So, a new class was created, *userProgress*, to store the necessary parameters that describe the progress. At present, these attributes are a *session-id*, the last *date* that the game was played, the *time* spent playing the game, the *score* the player has up to that point, and

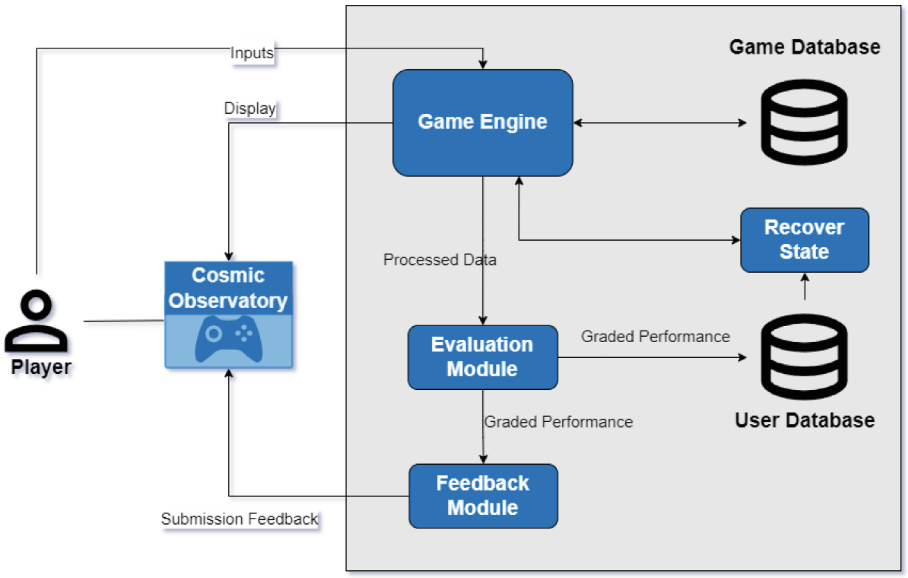

Fig. 2. Architecture Diagram.

the *game level* he is in. Finally, the *game* class was defined to store all *parameters* associated with the game, including the specific *scenarios* for each challenge and other details.

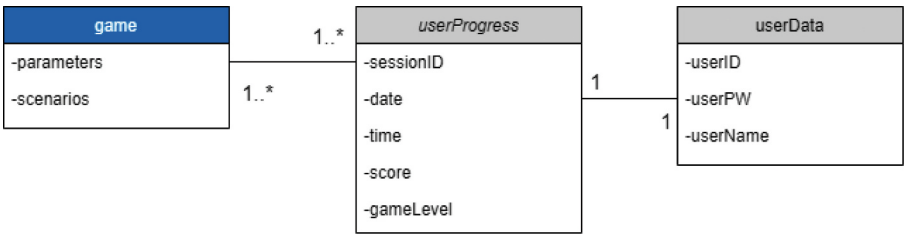

Fig. 3. Class Diagram.

5 Cosmic Observatory, the Game

In this section, the proposed game, *Cosmic Observatory*, is described. From a general introduction, and narrative to the challenges, the game details will be provided. As mentioned earlier, this game serves as an innovative educational tool, seamlessly promoting CT, more specifically, targeting the enhancement of pattern recognition skills.

5.1 Game Overview

Cosmic Observatory is an immersive educational game (Learning Resource) that combines the wonder of exploring the cosmos with puzzle-solving. Players take on the role of Celestial Explorers tasked with restoring harmony to the celestial archives by solving puzzles, deciphering cosmic mysteries, and interacting with ethereal celestial creatures. To summarize, it can be characterized as follows:

- **Title:** *Cosmic Observatory*
- **Genre:** Educational, Puzzle, Exploration
- **Platform:** Virtual Reality
- **Target Audience:** All age groups interested in astronomy, science, and exploration.

5.2 Game Play Features

The major features that *Cosmic Observatory* offers are:

Virtual Exploration – Players navigate through beautifully rendered virtual environments representing celestial landscapes, including iconic constellations, planets, and galaxies.

Celestial Puzzles – Players have to solve a variety of puzzles related to astronomy, such as matching constellations, arranging planets, and solving celestial crosswords.

Cosmic Creature Interaction – Players will meet ethereal cosmic creatures that provide clues and guidance throughout the celestial journey.

Educational Content – Players will learn about astronomy concepts, historical significance, and cultural myths associated with celestial objects.

Progressive Difficulty – Celestial puzzles and challenges become progressively more complex, catering to both casual players and those seeking a more challenging experience.

Narrative-driven Exploration – As players progress through the game, an engaging narrative reveals the history and secrets of the celestial archives.

5.3 Narrative

Players embark on a celestial journey to restore harmony to the Lost Library of Alexandria, now manifested as the *Cosmic Observatory*. Guided by celestial beings, players explore various celestial realms, solve puzzles, and interact with mythical creatures to unveil the cosmic mysteries hidden within the virtual observatory.

5.4 Game Mechanics

The mechanics of the game is described by the following elements:

Pattern Recognition – Celestial puzzles require players to recognize and replicate patterns associated with stars, planets, and cosmic phenomena.

Interactions with Cosmic Creatures – Players interact with ethereal beings, gaining insights and solving challenges with their guidance.

Educational Elements – Informational pop-ups provide educational content related to astronomy, enhancing players' understanding of celestial objects.

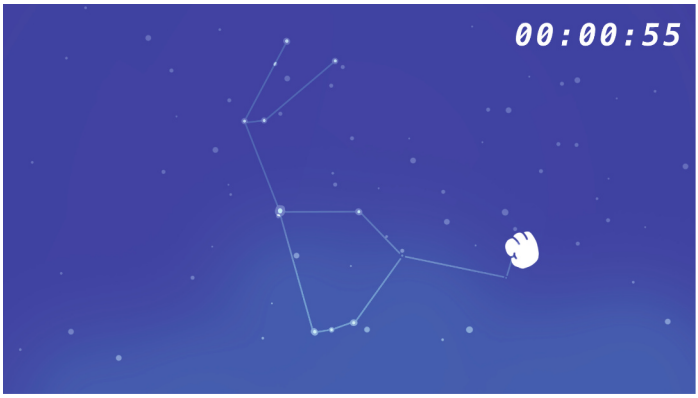

Fig. 4. Challenge 1 – Constellation Connections.

5.5 Celestial Challenges

Along this subsection, the ten challenges that compose *Cosmic Observatory* will be explained.

1. *Constellation Connections:* In this first challenge, players engage in pattern recognition by tracing celestial lines to connect stars within a given constellation, revealing hidden patterns in the night sky. As players decipher the interconnectedness of stars, they enhance their ability to analyze situations and to recognize patterns, fundamental aspects of CT (see Fig. 4).
2. *Planet Orbits Challenge:* The Planet Orbits Challenge tasks players with arranging planets in the correct order of their orbital distances from the sun, promoting algorithmic thinking. By strategically organizing the planets, players develop their ability to sequence and order objects systematically, a crucial skill in computational problem-solving (see Fig. 5).

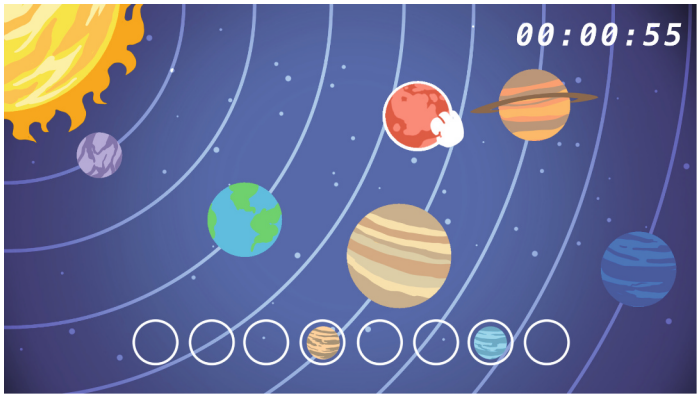

Fig. 5. Challenge 2 – Planet Orbits Challenge.

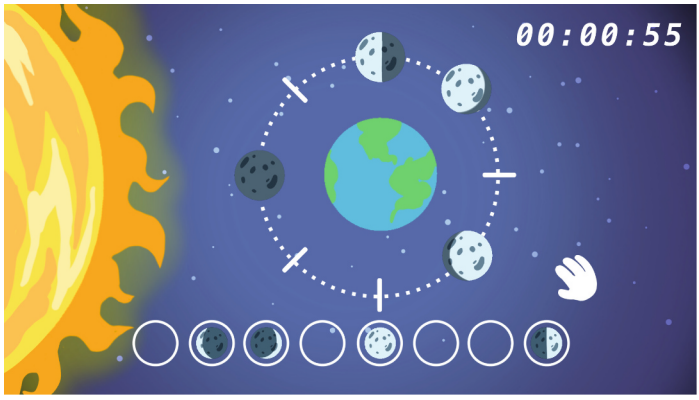

Fig. 6. Challenge 3 – Eclipsing Moons.

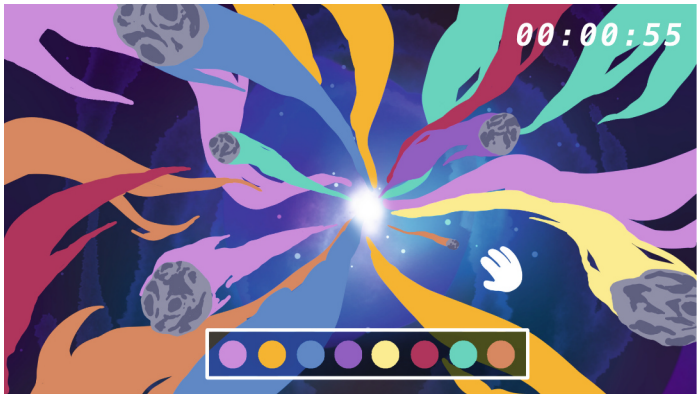

Fig. 7. Challenge 4 – Meteor Shower Memory.

Fig. 8. Challenge 5 – Galactic Alignment Puzzle.

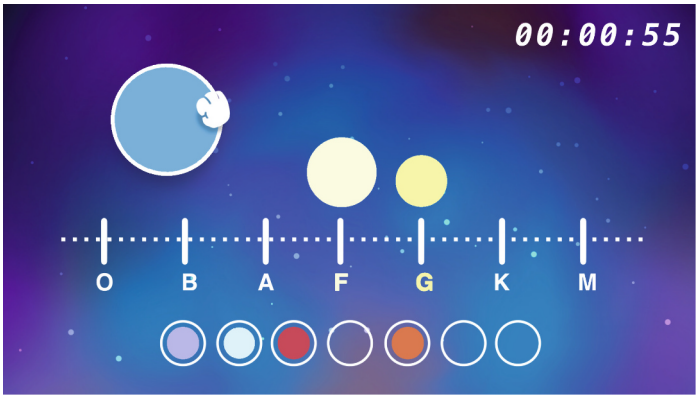

Fig. 9. Challenge 6: Stellar Spectrum Sorting.

3. *Eclipsing Moons:* In the third challenge, where players are required to match moons to their respective planets during various lunar phases, they engage in algorithmic thinking as they discern the dynamic relationships between celestial bodies. By analyzing patterns and sequences of lunar phases, players refine their ability to develop and implement algorithms to solve complex problems (see Fig. 6).
4. *Meteor Shower Memory:* In this memory recall exercise, players must remember the sequence of meteors during a simulated meteor shower, improving their memory skills. By remembering and organizing sequences of events, players strengthen their memory retention capabilities on the one hand and algorithmic thinking on the other hand, an essential component of CT (see Fig. 7).
5. *Galactic Alignment Puzzle:* This puzzle challenges players to arrange celestial bodies in a line to represent a galactic alignment, fostering spatial reasoning.

By manipulating and visualizing spatial arrangements of celestial objects, players develop their spatial reasoning skills, crucial for problem-solving and decision-making in computational contexts (see Fig. 8).

6. *Stellar Spectrum Sorting:* By categorizing stars according to their spectral characteristics, players enhance their ability to analyze and organize data, an important aspect of CT. (see Fig. 9).
7. *Orion's Belt Matching:* Identify stars within Orion's Belt, promotes problem decomposition skills. By breaking down complex celestial arrangements into smaller, more manageable components, players refine their ability to decompose problems, an essential ability for effective problem-solving in computational contexts (see Fig. 10).
8. *Celestial Crossword:* Solve a celestial-themed crossword puzzle, reinforces domain-specific language proficiency. By comprehending a provided clue, as illustrated in Fig. 12, the player engages in a word-guessing effort, employing a trial-and-error methodology to explore various possibilities until a fitting one emerges. This heuristic algorithmic approach mirrors problem-solving strategies. Additionally, if a chosen word proves incorrect, the player is required to revert to the previous game state (see Fig. 11), performing an exercise in error identification and solution refinement.
9. *Nebula Jigsaw:* Reconstruct captivating cosmic images in a jigsaw puzzle featuring famous nebulae or galaxies, fosters algorithmic thinking. By systematically arranging puzzle pieces to form cohesive images, players develop their ability to devise and implement step-by-step procedures, a key aspect of computational problem-solving (see Fig. 13).
10. *Telescope Calibration:* Refine observational skills by adjusting a virtual telescope to focus on specific celestial objects, based on provided clues, enhances algorithmic thinking. By analyzing clues and making precise adjustments, players strengthen their ability to formulate and execute systematic procedures, another essential capacity for effective problem-solving (see Fig. 14).

5.6 Cosmic Creatures Clues

We list below the clues that will be provided to the players while they solve the challenges described in the previous subsection.

1. Constellation Connections: "Seek the cosmic hunter, and draw lines to connect the bright stars forming a bow and arrow in the night sky".
2. Planet Orbits Challenge: "Arrange the planets, starting with the innermost, where the Sun's warmth embraces the rocky realms".
3. Eclipsing Moons: "Match each moon to its planetary partner, following the dance of shadows and light through the lunar phases".
4. Meteor Shower Memory: "Witness the cosmic fireworks and remember the fleeting meteors' order as they paint trails across the celestial canvas".
5. Galactic Alignment Puzzle: "Align the celestial bodies in a cosmic order, tracing the invisible threads that connect them across the vastness of space".

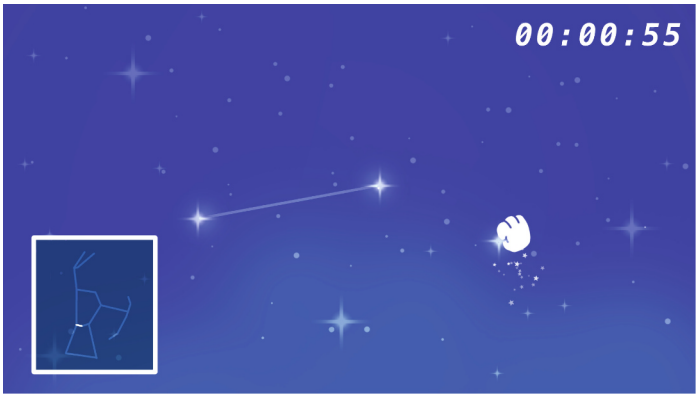

Fig. 10. Challenge 7: Orion's Belt Matching.

Fig. 11. Challenge 8: Celestial Crossword.

Fig. 12. Challenge 8: Celestial Crossword.

Fig. 13. Challenge 9: Nebula Jigsaw.

Fig. 14. Challenge 10: Telescope Calibration.

6. Stellar Spectrum Sorting: “Sort the stars by their radiant hues, unveiling the rainbow of cosmic light that fills the night sky”.
7. Orion’s Belt Matching: “Look to the mighty hunter and match the stars that form the distinctive three-star belt, guiding his celestial quest”.
8. Celestial Crossword: “Solve the puzzle with celestial clues, where the answers reveal the cosmic secrets hidden in words”.
9. Nebula Jigsaw: “Piece together the celestial clouds, revealing the breathtaking beauty of a stellar nursery or distant galaxy”.
10. Telescope Calibration: “Adjust the lenses to focus on the cosmic wonders, guided by the clues that reveal the specific celestial objects waiting to be unveiled”.

5.7 Integration of Challenges and Clues

The Celestial Puzzles and Cosmic Creatures Clues are intricately woven into the narrative, requiring players to solve puzzles to unlock clues, guiding them through the celestial journey. The successful completion of puzzles not only advances the game but also reveals deeper insights into the cosmic mysteries. Each individual puzzle or challenge is presented at a time, contributing to a cohesive whole, as the game design strategy is to follow a linear path structure. Linear pathways are preferable as they enhance players comprehension, facilitate a smoother narrative flow, and enable effective timing and pacing [4,7].

5.8 Educational Objectives

The game places an emphasis on training players in pattern recognition, an important skill of CT. However, it also promotes problem analysis, decomposition, and algorithmic thinking, requiring from the players the development of these skills to properly order simple instructions or elements to solve each task. Through celestial puzzles and challenges, players develop their ability to identify, analyze, and apply patterns. This is an essential skill applicable in various fields, including science, technology, engineering, and mathematics (STEM). The immersive celestial landscapes serve as a dynamic platform for honing these cognitive skills.

5.9 Graphical User Interface

The Graphical User Interface (GUI) in Celestial Observatory is thoughtfully designed to provide an intuitive and immersive experience for players exploring the wonders of the cosmos. A building for the game was conceived, where the architectural plan can be seen in Fig. 15 and a basic 3D render of it is shown in Fig. 16.

During game-play, the interaction interface seamlessly integrates with the controllers, enabling players to interact with celestial objects, solve puzzles, and navigate the immersive environments. Each of the ten puzzles features a unique interface tailored to the specific celestial challenge, offering a visually captivating and educational experience. From constellation connections to nebula jigsaw puzzles, the GUI adapts dynamically to provide informative clues, progress indicators, and an overall aesthetic that enhances the player immersion. With minimalist visuals for main menus, options, and puzzle interactions, the GUI in *Cosmic Observatory* ensures that players have an engaging and visually stunning journey through the wonders of the universe.

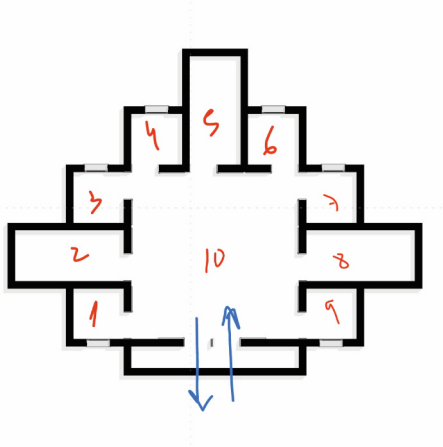

Fig. 15. Architectural Plan.

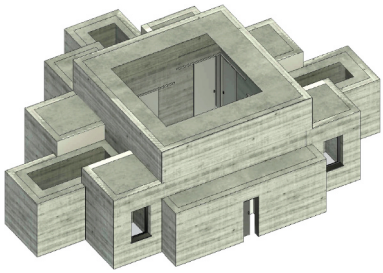

Fig. 16. Celestial Observatory 3D Render.

6 Conclusion

Computational Thinking is essential in children's education as it provides them with a set of cognitive skills to face the increasingly digital and technology-driven world. By fostering CT at an early age, children develop the ability to analyze complex problems, break them down into manageable components, and identify patterns - a skill set that transcends the boundaries of computer science and permeates various aspects of daily life.

This paper focuses on the design of a game, Cosmic Observatory, which leverages VR to promote CT through an astronomy theme, allowing students to explore the cosmos while solving puzzles. The observatory aims to captivate players with a mesmerizing journey through the cosmos, blending education with entertainment. This game proposal outlines the key features, mechanics, and objectives to create an immersive and educational VR experience for celestial enthusiasts of all ages.

The game development is planned to employ the Unity3D engine, primarily targeting desktop computers, with subsequent adaptation for VR devices. The following steps involve game tests and experimental sessions, for evaluating and improving its usability, interactivity, and overall performance.

As future work, new scenarios can be developed, associated with different CT skills, a gaming platform supported by devices, in such a way that the game is available with physical immersion and also an extension for games associated with mobile devices. The research highlighted the relevance of the topic and the potential for the development of serious and educational games for teaching and learning applications. The proposed architecture is extensible and can be adapted for new narratives and challenges. Finally, the proposed game can be enhanced to synchronize and store data from students' interactions. This extension, developed in a secure environment and integrated with analytical tools, can provide teachers with actionable insights and improve the game's effectiveness.

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The Process of Implementing International Accounting Standards: The Mozambican Public Administrative Sector

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Abstract. The aim of this study is to analyze the process of implementing the new public accounting system in Mozambique, in the light of normative and positive accounting theory. The methodology used to carry out this research consists of a case study, using the interview method, with a sample of 21 employees from a Mozambican public entity. It contributes to the growing literature in the public sector and the importance of different institutions promoting technological and pedagogical innovation strategies for the advancement of qualified professionals. The relevance of the study is due to its topicality and the fact that the subject is studied little in developing countries. The results obtained suggest that the process of implementing the new Public Accounting Subsystem in Mozambique is a major challenge for all those involved, from the definition of clear procedures to a feasible implementation process, which requires a well-structured accounting and technological training plan for employees.

Keywords: Case Study · Developing Countries · Education · IPSAS · Public Sector · Technologies

1 Introduction

In recent decades, several public sector accounting reforms have been implemented around the world to improve the harmonization and comparability of public sector financial reporting [1]. In 2020, the Mozambican government approved Law No. 14/2020, of December 23, to allow better monitoring of the budget process and the management of public finances, with economy, efficiency, and effectiveness. This Law brings with it the Public Accounting Subsystem (PAS) - Section II and Subsection I, of Chapter II - Subsystems of SISTAFE - which refers to the implementation of the convergence process with the International Public Sector Accounting Standards (IPSAS) [2]. The adoption of IPSAS is a relatively new field of research in the public accounting literature regarding specific issues in the field of IPSAS [1]. The study by Liberato et al. [1] shows that there are constraints and incentives in the implementation of accounting

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standards between developed and developing countries in the reform of public accounting. Adedeji [3] points out that most studies on the extent of IPSAS adoption have been carried out in developed economies. Many developing economies are still adopting cash accounting, such as the government of Zimbabwe and other West African countries. It should be noted that the application of IPSAS is one of the subjects that has also been the focus of the study of accounting information systems [4]. Although the United Nations has designated quality education as the fourth Sustainable Development Goal (SDG), developing countries and countries with emerging economies still lack the impact of Information and Communication Technologies (ICT) on education and learning using digital technology [5].

It is considered that the adoption of new reforms, such as the implementation of IPSAS, supported by the teaching and technologies of current accounting information systems (AIS), can be related to both the normative theory and the positive theory of accounting. These theories explain the adoption and success or failure of the implementation of accounting standards, by those preparing new practices and systems [6]. Both processes are influenced by accounting standards, government regulations and corporate governance practices that seek to guarantee the transparency, comparability and relevance of the financial information disclosed by organizations, to meet the expectations of stakeholders in relation to the accountability and responsibility of entities. In this context, the normative theory of accounting is concerned with establishing accounting standards and principles that guide the preparation and presentation of financial information in accordance with ethical criteria and in public interest. On the other hand, AIS are seen as tools that provide useful information for users to make decisions. It is therefore up to the positive theory of accounting to describe and explain how IPSAS and AIS are used in practice, without value judgments.

2 Literature Review

2.1 Normative Theory in Accounting Research

The period between 1956 - 1970 was considered the period of normative accounting theory because in this period accounting theory sought to establish standards for best accounting practices. Normative theory does not involve hypothesis testing and, for this reason, cannot be tested empirically, because it is not possible to prove empirically what should be [7]. It is concerned with identifying ethical principles and standards that guide accounting practices, as well as verifying what data should be communicated and how it should be presented to the various users of accounting information, with more emphasis on investors [8]. The same author considers that accounting theory with a normative approach is built on deductive reasoning, which starts from the generality of accounting postulates and principles, which will serve as the basis for accounting practice. Normative theory is essentially prescriptive, with the aim of indicating how accounting practice should be done or how it should work. According to Martins [9], normative research is concerned with evaluating accounting practices according to theoretical standards of what is considered ideal, proposing best practices. The same author adds that normative research, aimed at recommending professional practices and procedures, arose from work carried out by academics who were members of the accounting profession, thus

linked to the problems of practicing the profession. The study of this theory rose with the research carried out by regulated accounting bodies such as the FASB (Financial Accounting Standard Board) in the USA and the IASB.

Normative theory is built on deductive reasoning that serves as the basis for accounting practice [10]. It relies mainly on the deductive method and derives from prescriptions of how accounting should proceed to maximize the usefulness of information for the various types of users [11]. These authors warn that the defect of this approach is the need for a long period of experimentation to verify whether the prescriptions have worked in the real world of accounting. It is a theory that identifies existing problems in accounting practice and proposes solutions, develops accounting standards to improve the consistency and transparency of financial information, proposes changes to accounting legislation to improve the efficiency and effectiveness of the accounting system, and assesses compliance with existing accounting standards and identifies areas where compliance needs to be improved [9]. Normative theory in accounting is fundamental because it seeks to establish principles and rules that guide accounting practice, investigating objectivity and impartiality in the presentation of financial statements. It is also essential for drawing up international accounting standards that can be used globally, providing a benchmark for accounting professionals to carry out their activities with transparency and zeal [10, 11]. They reiterate that the normative theory helps establish the basis for the development of international accounting standards used by various countries worldwide, such as the IFRS and the IPSAS. In addition, the normative theory guarantees the reliability and comparability of financial information, which is one of the fundamental qualitative characteristics of financial information for decision-making by users.

2.2 Positive Theory in Accounting Research

Positive theory began to emerge at the end of the 1960s, because of the loss of importance of normative research, whose recommendations for action for entities and managers were of the "what should be" type of accounting practice. Positive theory, on the other hand, provides predictions based on the study of the reality of the facts, with the question of study being "what is" [12] (Major & Vieira, 2009). The work by Ball and Brown (1968) [13], entitled "An Empirical Evaluation of Accounting Income Numbers', was an important milestone in accounting research, where the central objective was the content of accounting information and its usefulness for decision-making by users, i.e. accounting information was positioned towards the capital market.

Watts and Zimmerman [14], in formulating the positive theory of accounting, seek to explain and predict managers' accounting choices based on the incentives they face. Managers, in their behavioral intuition, always try to choose the accounting policies that maximize the company's wealth (or their own), while minimizing contractual costs. The formulation of this theory, according to the authors, is geared towards organizations, with the following works standing out: the motivation of managers to make accounting choices using Gordon's 1964 model, the theoretical explanation of contracting costs and the relationship between "the principal and the agent" by Jensen and Meckling in 1976. Positive accounting theory contributes to the reflection that accounting information has on the capital markets, the influence of accounting on the function of managers'

behavior and the theory's power to explain and predict the events studied [15]. It is a theory that influences the development and use of accounting information systems in decision-making and financial performance analysis. The normative side aimed to prescribe (what should happen) while the positive side aimed to explain and predict (what happens and what will happen). Normative economic theory builds models and tools to help companies achieve results under optimal conditions. Positive economic theory develops theories and models that describe and explain how and why economic agents reach equilibrium conditions [16].

2.3 Mozambican Public Accounting Subsystem

The financial activities of public sectors characterized by financial impropriety are attracting significant global interest and debate among policymakers and academics around the world, especially in developing economies to reposition their public service with new reforms [3]. The new Mozambican PAS perceives new public accounting requirements, in addition to a cash and commitment perspective, for an accrual basis perspective, according to which events and transactions are recognized in the financial statements when they occur and not only when there is a payment or receipt. Accrual-based financial reporting provides more complete, reliable, and objective information on the financial position and performance, contributing to quality management control, decision-making and the economic, efficient, and effective allocation of resources [17]. The current accrual basis has made a decisive contribution to obtaining a set of extremely important information at all stages of the budgetary process, helping to provide useful information for decision-making and accountability. Thus, only with high-quality accounting standards is it possible to understand the financial position and results of public administration, as well as providing information to users for more efficient and effective decision-making [18]. The IPSASB recommends that governments start preparing their financial statements on an accrual basis. These standards seek to improve the quality and transparency of public sector financial reporting, providing useful information for public sector financial management in decision-making [19, 20].

The existence of differentiated accounting, such as results according to the country where the entity is located, is not acceptable in a globalized economy, where the comparability of financial information and accounting harmonization are one of the reasons for the importance of international accounting [21]. Thus, accounting harmonization is indispensable for accounting, as it is only possible to compare entities whose financial statements have been drawn up based on the same principles and rules, thus enabling the effectiveness and efficiency of the entity to be assessed, whether it is private or public [22]. The phenomena of internationalization and the globalization of the economy, the growing economic, financial, and political interdependence between nations, have influenced financial information. Users of information are increasingly interested in the homogenization of accounting policies and standards to be followed in capital markets at a global level [23]. Users demand homogeneous, comparable, and understandable information [24]. International accounting harmonization is the result of the globalization of economies and capital markets. Its widespread adoption eliminates accounting differences, thus creating more integrated, liquid, and deeper financial markets and services, improving the efficiency of capital issuance, and protecting investors [25].

The IPSAS issued by the International Public Sector Accounting Standard Board (IPSASB) aim to increase the quality of accounting information and transparency in the sector. These standards provide extensive information for the financial management of the public sector, as well as disseminating guidelines related to public sector financial reporting and decision-making [18]. The New SISTAFE Law contains a set of provisions regarding the PAS, where it gives PAS bodies powers to draw up harmonized and uniform recording standards and procedures that are accepted at international level or that comply with the IASB. The new law introduces new powers that make a greater contribution to improving the PAS, as they aim to comply with efficient, effective, and internationally accepted internal control standards and procedures, which are extremely important for the transparency of financial information and convergence with international public sector accounting standards. And yet, in a scenario of high rates of fraud and embezzlement of public funds, the action provided for in the competence to prevent unethical and uneconomic practices, leads us to manage public affairs with diligence and honesty [2]. The appearance of public sector financial statements is often marred by inadequate and improper disclosure of financial and accounting information [17]. The process of economic integration and the need for comparability of accounting information are still the challenges of accounting harmonization for the public sector at international level.

3 Methodology and Methods

This research explores on the ground, in contact with real situations, and based on observation, how the process of implementing the new public accounting in Mozambique is taking place, in the light of normative and positive accounting theory, following Law No. 14/2020. This empirical case study investigates a current phenomenon in depth and exhaustively, in the context of a reality [26, 27], allowing for broad and detailed knowledge [28, 29]. Qualitative methodology using the case study method that provides tools for researchers to study complex phenomena within their contexts and, when applied correctly, becomes a very valuable mode for research in developing theories and evaluating programs [30]. There is a deepening of understanding of a social group or an organization, characterized by describing, explaining, and relating the global and the particular of a given phenomenon [31], of emerging issues [5], similar to Adedeji [3] who investigated the extent of the adoption of IPSAS in Nigeria, with a case study.

Data was collected by interviewing 21 employees from the National Directorate of Public Accounting (NDPA), with each interview lasting between 15 min and 30 min for each interviewee, in 2023, the body responsible for drawing up standards and procedures for accounting records, 17 of whom were from the Public Accounting Department and 6 from the Standardization, Procedures and Supervision Department. A semi-structured interview script with open and closed questions, similar to Adhikari et al. [32], was drawn up beforehand. This type of interview is one of the main tools for qualitative research, as there are no rigid questions, and it allows the interviewee to respond on the subject and within the framework of the study [33]. This research makes it possible to understand, interpret and explain in greater depth the practices of social phenomena [34, 35], the opinions or experiences of employees, to gain in-depth insight into a problem or generate new research ideas [5, 26]. To interpret the set of activities, it uses narratives,

speeches, and archives, and may even resort to statistics, tables, graphs, and numbers, although it is not quantitative research [36]. The study devoted more effort to obtaining detailed answers from the interviewees and used as many sources as possible, such as interviews, reports, observations, and documents, to draw reliable conclusions and report on the case, as did Tetteh et al. [5].

4 Analysis and Discussion of Results

Based on the research question raised, the aim was to understand and analyze the process of implementing the new public accounting in Mozambique, in the light of normative and positive accounting theory. The analysis and discussion of the results of this study is based on the interviews carried out, as NDPA employees. The interviewees were aged between 30 and 50, mostly female (67%), all with more than 6 years' service at the NDPA. These employees have received training in the last 2 years related to: IPSAS (56%), Public Finances (22%) and ICT (software and e-SISTAFE) (22%). This was given by the Center for the Development of Financial Information Systems (CEDSIF), the International Monetary Fund (IMF) and the Order of Accountants and Auditors of Mozambique (OCAM). These are officials with experience in the civil service and who have knowledge of accounting, particularly public accounting.

Even though most of the employees have higher education in business and economic sciences, it was observed that, on the one hand, the majority of NDPA employees claim to know the causes that gave rise to Law No. 14/2020 (17 employees), its subsystems (16) and are aware of the main changes to this Law in the SCP (15). On the other hand, there was reduced knowledge in matters of accounting assumptions in the light of the IPSAS (10 employees) which will compromise its implementation process (see Table 1).

Table 1. Level of knowledge of the new Law

Nature of the Questions - Law nº 14/2020	Very low		Low		Medium		High		Very high		Total
	no.	%	no.	%	no.	%	no.	%	no.	%	
1. Causes that gave rise to Law 14/2020.	1	5%	2	10%	3	14%	8	38%	7	33%	21
2. The subsystems of Law 14/2020.	1	5%	4	19%	3	14%	8	38%	5	24%	21
3. Main changes brought by Law 14/2020 in the Public Accounting Subsystem (PAS).	4	19%	2	10%	5	24%	4	19%	6	29%	21
4. The accounting assumptions for the amendment to Law 14/2020 in light of IPSASs.	5	24%	6	29%	5	24%	3	14%	2	10%	21
Average	**3**	**13%**	**4**	**17%**	**4**	**19%**	**6**	**27%**	**5**	**24%**	**21**

This fact can be justified because these are new matters at the level of national and even international Public Accounting. These results also confirm the experience of other countries, such as Tanzania, Portugal, Nigeria, and New Zealand, where IPSAS training is one of the important challenges for the implementation of IPSAS and effective accrual basis accounting [37–42]. Adhikari et al. [32] drew attention to public sector accounting professionals, who must understand the importance of considering the specific contexts of emerging economies to avoid facing delays and resistance in reforms. They highlight

the following as contextual elements to emphasize power structures, communication channels, informal networks, and communication flows, prior to the diffusion of reforms. Regarding the nature of the closed questions present in the interview guide, relating to changes and impacts on the PAS, it appears that 19 of the employees agree that they have knowledge of the PAS present in the new Law, as well as being unanimous in agreeing that the set of statements Financial institutions established by Law 14/2020 provide true and appropriate information on transactions and are important for the transparency of public accounts. Regarding the issue related to the change in the paradigm of the State's accounting process, 20 employees believe that a paradigm shift will occur.

Regarding the issues of qualification and training of personnel for the implementation of the IPSAS process, all respondents consider that the insufficient qualification of human resources in terms of IPSAS will be one of the major obstacles in the implementation of the PAS. They also consider that the Mozambican State must improve training actions in IPSAS matters in order to effectively implement Law 14/2020. The same concluded Abdulkarim et al. [6], that professional accountants with high ethical conduct and who receive technical support are essential for the successful implementation of IPSAS, based on competence. Yet the implementation of accumulation-based IPSAS is motivated by external pressure exerted by regulatory agencies over non-compliance with standard requirements and the fear of losing donor-funded projects. Slama et al. [43] reinforce the importance of a strategy for adapting local standards to the IFRS, despite the challenge of the considerable cost in terms of time and money to be borne.

To triangulate the closed questions, the interviewees were asked open questions. Thus, some interviewees considered the difficulties experienced on the ground in implementing the new law (1st open question) to be related to the insufficient qualification of human resources in IPSAS matters, which is why they sought advice from the team at the National Board of Accountants and Auditors (NBAA), which has some experience in implementing IPSAS in Tanzania. Pauluzzo et al. [44] revealed the lack of a practical perspective for the development of accounting skills for graduates and civil servants, capable of bridging the gap between teaching and the requirements for practice in the current public sector context. In addition, Spyridon and Karastogiannis [45] point out that the difficulty in introducing and applying accrual accounting (in Greece) may also result from inadequate human resources and the mentality and culture of employees in resisting change. In the analysis of the degree of preparation of the NDPA human resources for the implementation of Law 14/2020 (2nd open question), most of the interviewees consider that the NDPA 's human resources are not sufficiently qualified and knowledgeable in asset accounting matters for the implementation of the IPSAS. This corroborates the view of Adhikari et al. [32] that education, training and awareness-raising among accountants and government administrators are essential for the implementation of accounting reforms in the public sector (the IPSAS). Public sector accounting education plays a crucial role in building a skilled workforce that can address the unique challenges of financial management in the public sector, thereby supporting the overall efficiency, transparency and accountability of government financial operations and accountability of public administration financial operations, ultimately benefiting citizens and the community at large [44].

Observing the level of preparation of public sector entities for the implementation of Law 14/2020 (3rd open question), the interviewees continue to point to the lack of sufficient human resources with knowledge of IPSAS in the public sector. This is one of the main obstacles in the process of implementing the Law. For this reason, the interviewees are unanimous in stating that the implementation of the Law would imply hiring new employees (4th open question), either internally, through the mobility of employees with IPSAS qualifications and experience or even hiring externally. As the implementation process is at the mapping and diagnostic stage, it is still possible to estimate the number of staff to be hired. Sellami and Gafsi [46] underline the need for governments to take the necessary actions and relevant measures to strengthen their public financial management mechanisms and to promote an effective and skills-based accounting education system capable of providing a more in-depth and adequate knowledge of IPSAS. This would help to create a framework of sound and ethical professionalism, transparency, control, and integrity, for greater compliance with accounting standards and improved public sector performance. The results of the study by Liberato et al. [1] suggest that there are differences between constraints and incentives in the implementation of accounting standards between developed and developing countries. They show that there are constraints %identified in both developed and developing countries, such as the lack of accounting knowledge and skills and the limitations of software and information technology. Adedeji [3] found that the adoption of IPSAS varied across the states of Southwest Nigeria. He believes that government sponsorship of local training programs for most of its staff is an indication of the value placed on human capital development in the public sector and probably a quest to improve performance in the sector. Macuacua's [47] study in Mozambique states that teaching and research in Public Accounting is very low and current accounting teaching does not meet the needs of the current PAS reform. The current study corroborates Professor Macuacua's study that improving training is a key element for the effective implementation of the PAS. The insufficient qualification of human resources, particularly in matters related to the IPSAS, jeopardizes the process of implementing the IPSAS in Mozambique.

These results are in line with the principles of normative theory. To provide accurate financial information, promote transparency, fairness, and accountability in accounting practices, it is necessary to prescribe regulations, such as the new law no. 14/2020, with ideal standards of conduct and accounting practices that reflect social, moral, and ethical values in addition to economic objectives. In this way, the public interest is protected, in accordance with the accounting principles of prudence, consistency and materiality, which guide the preparation and presentation of financial reports. It is the guarantee that the financial information is relevant, reliable, and comparable for external users, as Martins [9] points out.

To explain and predict the PAS implementation process in Mozambique, positive theory allowed the development of models based on the analysis of empirical observation of the behavior of interviewees and the relationship between the accounting and economic variables of the study. It allowed us to observe how the information collected is interpreted and used in decision-making. The positive theory supports the study in predicting the future behavior of economic variables and being tested empirically to verify their effectiveness in practice. That is, teaching and training in accounting and

technologies are crucial for the efficiency and effectiveness in implementing the PAS in Mozambique.

5 Conclusions

This study aims to analyze the process of implementing the new public accounting in Mozambique, in the light of normative and positive accounting theory, using a case study. It was possible to ascertain that Mozambican employees and public entities are not prepared for the implementation of Law no. 14/2020 at PAS level. Despite awareness of its importance and the ongoing work to implement the IPSAS, the process of implementing the current law is still a challenge. There is a long way to go, starting with the appropriate training and qualifications of employees, as well as the adaptation of IT systems. The greatest difficulty in implementing this law is related to the insufficient qualification of human resources in IPSAS matters, with employees who are sufficiently qualified and knowledgeable in these matters, as well as in the new computer applications to be used. The same was true of Abdulkarim et al. [6], who recommended the need to encourage accounting staff to acquire more qualifications that will enable them to become qualified accountants, which will facilitate the rapid implementation of the IPSAS based on the accrual basis of accounting. They should also ensure that accounting staff are fully involved in professional training, seminars and conferences organized by professional accounting bodies. As the IPSAS implementation process is a new experience, there is a need to turn to some countries with extensive experience in this process, such as Tanzania, South Africa, Australia, New Zealand, the United Kingdom, Canada and Portugal, which has a system like the national PAS. For the successful adoption of the IPSASs, there is a need to develop relevant communication and change management strategies, resources and elements for regular updates in order to reduce resistance to change and motivate stakeholders. In addition, it is recommended that the government leaders responsible for the IPSAS adoption program, in this case the Minister of Economy and Finance, should play an influential role in the implementation process, providing timely support, guiding orientation sessions with the IPSAS implementation team, explaining the impact and benefits of the IPSAS implementation program for their functional areas. Another aspect that must be taken into account is the effort that must be made with a "we can do it" attitude, in order to avoid setbacks or even the hibernation of activities.

The results obtained suggest that the process of implementing the new PAS in Mozambique is a major challenge for all those involved, from the definition of clear procedures to a feasible implementation process, which requires a well-structured accounting and technological training plan for officials. It is well known that the digital transformation of society is profoundly altering the practices of public service provision and favors the creation of public value. The changes that will characterize accounting processes in the public sector due to the adoption of IPSAS and the national standards based on them require graduates and civil servants with adequate knowledge of the public sector accounting context and the characteristics of international standards. IPSAS does not yet play a significant role in current higher education programs to meet the future challenges that IPSAS and EPSAS will pose [44].

We can see that the process of implementing the new PAS, particularly in the light of the IPSAS, must be supported by normative theory that presents how it should be done or how accounting practices should work, both at the level of government institutions, professional bodies and educational institutions. Clear technical standards and guidelines are needed, as well as the planning of the stages of the process and its follow-up, monitoring and evaluation, by suitably qualified staff and supported by the new AIS and emerging and regenerative technologies. Accounting professional faces new challenges in the face of regulatory changes and evolving accounting standards, the globalization and complexity of financial transactions, technological advances and digitalization, and ethical and social responsibility challenges. There is a need to update and adapt education and training systems, with AIS to meet emerging challenges. It is also relevant and significant, particularly in developing countries, that governments and public managers encourage, promote and develop career systems that are conducive to the exercise of these functions and to the system of lifelong learning in an era that is constantly changing and evolving. Consequently, positive and normative theories remain relevant to addressing the new challenges faced by accounting professionals.

As Pauluzzo et al. [44] pointed out, public sector reforms, e-government and digitalization have challenged the traditional skills of civil servants, creating a demand for new qualified accountants for public entities capable of dealing with the complexity and dynamics of today's public sector. Liberato et al. [1] stated that informed decision-making allows public managers to make more effective choices and to face the challenges associated with this transition process in reforms. They contribute to promoting a more transparent and accountable public sector, increasing trust and accountability between government and society.

The study's conclusions have the potential to contribute to the literature, government and public decision-makers, associations and other professional bodies, educational and training institutions, as well as the community in general, with social implications. The conclusions also have practical relevance for public organizations involved in implementing public accounting, specifically international standards such as IPSAS. The study's insights can help these organizations face the challenges and opportunities that arise during the implementation process. By providing new evidence of differences in perceptions and gaps in teaching-learning processes, the study contributes to the accounting education literature in developing countries and emerging economies, similar to Tetteh et al. [5].

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Service Quality, Satisfaction and Loyalty Determinants in the e-banking

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Abstract. In recent years, there has been a notable increase in the use of e-banking. In recent times, online technologies have revolutionized the process of relationship building between firms and their customers. A reality that has led financial institutions to be increasingly closer to their customers and to make their services available on the most diverse distribution channels. Given Portugal's wide range of banking services, these new marketing trends may impact consumer choice and preference. This paper aims to study the determinants of e-loyalty involved in the banking sector's relationship with its customers from the perspective of relational marketing online. In this way, internet banking and interactivity are essential variables in achieving quality of service in e-banking. In turn, quality of service proved to be a fundamental antecedent of customer satisfaction, and these two variables determine customer loyalty to the use of e-banking. Therefore, e-service quality and e-satisfaction mediate between the independent variables, internet banking and interactivity, and the final variable, customer e-loyalty.

Keywords: Loyalty; Satisfaction · Service Quality; e-Banking

1 Introduction

In today's challenging and competitive environment, sustainable and profitable relationships with customers are evidenced by organizations more than anything else. The banking industry is no exception to this rule, and to attract and retain customers, it looks for different management strategies [1].

Internet banking is gaining popularity in the banking industry, a new dimension expected by bank customers. Besides having tangible equipment such as conveniently located ATM facilities, bank users also look at advanced technology to carry out their banking transactions anytime, anywhere [2]. Interactivity can be explained as the degree to which a dialogue can be established between a firm and its customers online, through information sharing [3]. Hence, internet banking and interactivity lead to quality service delivery. Customers will be happier and loyal to the bank provider if a good service quality is perceived. This finding is further supported by past researchers, who have

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found a significant relationship between online service quality and customer satisfaction [2].

Customer loyalty has been vital to improving any business's customer relationships and profitability +, as established by several studies. In e-banking, the challenge of keeping customers loyal is twofold due to two major concerns: greater susceptibility to customers' switching in the web domain and the absence of human interaction, which can weaken customer relationships and personal touch as in retail banking. These factors make it an extremely daunting task for banks to keep their customers loyal. Besides, the banking sector's minimal product and price differentiation has compelled banks to focus on offering superior-quality products and services to differentiate themselves from competitors [4]. Thus, delivering superior quality has become the most imperative factor to enhance customer satisfaction and build customer loyalty in e-banking. Hence, earlier studies have considered perceived quality and customer satisfaction essential drivers of customer loyalty [5, 6].

In this way, we will consider e-service quality and e-satisfaction as direct antecedents of e-banking loyalty. We believe internet banking and interactivity are indirect antecedents of e-banking loyalty. Therefore, e-service quality and e-satisfaction are direct determinants of e-banking loyalty and mediating variables between the independent variables, internet banking and interactivity, and the final variable, e-banking loyalty.

2 Theoretical Framework and Research Hypotheses

This section presents the theoretical framework that supports constructing our research model, whose final variable is loyalty to electronic banking. We propose a model in which e-service quality and e-satisfaction are mediating variables between the independent variables, internet banking and interactivity, and the final variable, e-banking loyalty. Thus, internet banking and interactivity are determinants of e-service quality. In turn, e-service quality is an antecedent of e-satisfaction and e-loyalty, and e-satisfaction is a determinant of e-loyalty.

Internet banking is using the Internet as a delivery channel for banking services, such as opening a deposit account or transferring funds between different accounts, and new banking services, i.e., electronic bills and payments [7]. The Internet has been accepted as a new channel of banking transactions. With the high growth of new technology, the increased use of the Internet greatly impacts the characteristics of subsequent services [8].

Interactivity can be explained to the degree to which a dialogue can be established between a firm and its customers online, through information sharing [3, 9]. There are four main aspects of interactivity: reciprocity, responsiveness, non-verbal information, and speed of response [10]. Although due to the spatial and temporal separation between firms and their customers online, all these aspects of interactivity are relatively complicated to achieve [9].

Internet banking and interactivity could be critical determinants of the quality of e-banking services. Zeithaml (1988) [11] defined perceived quality as the consumer's judgment about an entity's overall excellence or superiority. This individual perception

is subjective, differing from the objective quality. The research on perceived quality can be traced back to earlier works in services marketing [12–16]. The quality of e-service is defined as a customer's experience with the service provider through a given electronic channel without human intervention [18]. In its most simplistic form, e-service quality is defined as "the consumer's overall evaluation and judgement of the excellence and the quality of the e-services offering in the virtual marketplace" [[45], p. 235]. Our study conceptualized overall perceived quality as the customer's evaluation of the quality of e-banking in terms of its product quality, customer service, and website quality.

In the literature, two main conceptualisations of customer satisfaction are distinguished. The first conceptualisation is transaction-specific satisfaction, which is associated with evaluative judgment of a particular "transactional experience with the firm" [17]. The second conceptualization is the cumulative satisfaction, which is allied to the "overall evaluation of purchase and consumption experience with a product or service provider over time" [17]. According also to Cheng and Chan (2009) [29], e-service can be categorized into two aspects, one could be referred as transaction specific in which the contentment is regarded as a sentimental response towards the performance on characteristics of a service while the satisfaction depending on the variables which occur due to the repetitive transactions is referred as cumulative result or overall satisfaction [30]. Cumulative satisfaction is retained in this study, not transaction-specific satisfaction. E-satisfaction is defined as the customer's pleasant sense due to the positive experience with an e-service [20].

Several studies point out a relationship between customer satisfaction and e-Banking services because they demonstrated that the degree of satisfaction of customers in the banking sector increases when using e-Banking services [19].

Loyalty is the repeated purchase behavior over a period driven by a favorable attitude toward the subject, including both attitudinal and behavioral aspects [20]. Hence, loyal customers frequently visit and recommend to others [21]. Therefore, service loyalty is based on a positive attitude and behavior toward a service provider, preventing customers from switching to another service provider [34]. Customer loyalty has two dimensions: attitudinal loyalty (the degree to which a customer considers a bank his or her top choice for banking services); and behavioral loyalty (the customer's tendency to seek continued service from the provider or to recommend the service to others) [35].

Various authors suggested that internet banking distinguishes itself from its competitors [22]. Internet banking is the use of the internet as a delivery channel for banking services, such as opening a deposit account or transferring funds between different accounts, and new banking services, i.e., electronic bills and payments [7]. The internet has been accepted as a new channel of banking transactions. With the high growth of new technology, the increased internet use significantly impacts subsequent services' characteristics. Jun and Cai (2001) found that the more positive the customer perception of internet banking, the greater the likelihood that overall service quality will be perceived [7]. Therefore, we consider the provision of high-quality internet banking to be influential to the overall service quality of the banking sector, as has been shown in some studies [2, 8]. Interactivity will also be a crucial determinant of e-service quality. Consequently, the following hypotheses are proposed:

H_1: Internet Banking has a positive effect on E-Service Quality.

H_2: Interactivity has a positive effect on E-Service Quality.

Significant research has analyzed the interrelationships between perceived quality, customer satisfaction, and customer loyalty [16]. Despite considerable ambiguity in the demarcation between quality and satisfaction, it can be assumed that these two constructs are distinct. But the logical question is about the order of their occurrence in the consumer's mind. Traditionally, researchers suggested that customer satisfaction with a given experience would lead to an overall evaluation or attitude about service quality over time [23]. However, the opposite view strongly argues that service quality is an antecedent of customer satisfaction, regardless of whether these constructs are measured for a given experience or over time [24]. The latter view of service quality being an antecedent of customer satisfaction has been empirically validated by some previous researchers [25–28]**.** Supporting this contention, in this study, e-service quality was hypothesized to significantly impact e-satisfaction as in other investigations [4, 8, 31, 32, 43, 46]. In this way, we propose the following hypothesis:

H_3: E-Service Quality has a positive impact on E-Satisfaction.

Service quality has been seen as a variable that directly influences loyalty, as well as a variable that indirectly influences loyalty, via satisfaction. In our study, we will study both the direct and indirect effects. In general, electronic service quality can be defined as the customers' evaluation and overall judgment concerning the superiority and quality of the services provided in the virtual market [21].

Previous research, in online banking services, demonstrated that service quality is an antecedent of loyalty [44, 46]. In banking, recent studies have shown that service quality impacts loyalty [4, 32, 35, 43, 47]. Consequently, we propose the following hypothesis:

H_4: E-Service Quality has a positive impact on E-Loyalty.

The body of literature that examines customer satisfaction and retention is the building block of the relationship marketing research domain. Specifically, it is argued that satisfied customers develop favourable behavioural intentions toward services such as self-service technologies [36, 37].

Satisfaction is one of the antecedents of loyalty in previous studies [5, 26, 38]. More recently, many authors argue that satisfaction drives loyalty in banking services [21, 31–33, 35, 39–43, 47]. Consumers who are satisfied with internet banking are more likely to have a consistent relationship with internet banking in the future and demonstrate more loyal behavior [21]. Accordingly, the following hypothesis is posited:

H_5: E-Satisfaction has a positive impact on E-Loyalty.

3 Research Methodology

Thus, the research model, presented in Fig. 1, was proposed, in which internet banking and interactivity influence e-service quality. In turn, e-service quality impacts e-satisfaction and e-loyalty. Finally, e-satisfaction influences e-loyalty. Therefore, we propose a model where e-service quality and e-satisfaction are mediating variables between the independent variables, internet banking and interactivity, and the final variable e-loyalty.

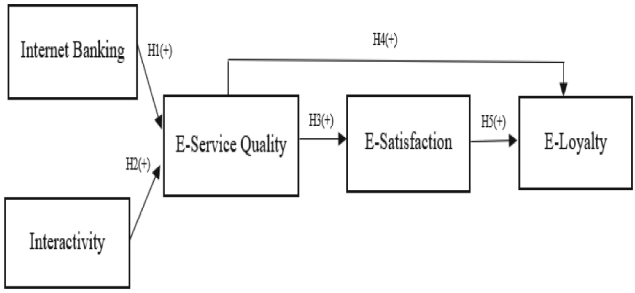


Fig. 1. Proposed conceptual model

3.1 Sample Selection and Data Collection

This research study used a structured and self-administered questionnaire that addressed all the information needed. A sample of convenient elements was obtained by using a non-probabilistic convenience sample. The survey was developed in an online format. For the present research, 207 responses were obtained. As to gender, we received answers from both genders, i.e., 39.6% were male and 60.4% female. Regarding age, there was a higher number of answers in the 18–24 age group, which represents 32.4%, and, immediately afterwards, in the 25–34 age group, which represents 30.9%. Regarding academic qualifications, the most representative respondents (38.2%) have a university degree, and a high school (29%).

3.2 Measurement Scales

The constructs' measurement scales were based on literature. All variables were measured on a seven-point Likert scale, ranging from 1—strongly disagree to 7—strongly agree (Table 1).

Table 1. Variable scales

Variables	Scales used
Internet Banking	[8]
Interactivity	[3]
E-Service Quality	[8]
E-Satisfaction	[40, 41, 42]
E-Loyalty	[4]

4 Analysis and Results

4.1 Measurement Model

An initial screening of each scale was conducted using item-total correlations and exploratory factor analysis (EFA) using SPSS 26.0. Following Anderson and Gerbing's (1988) [49] two-step approach, a measurement model was estimated before testing the

hypotheses, using a structural model. The data was analyzed through confirmatory factor analysis (CFA) and structural equation modeling (SEM) using the statistical software AMOS (Analysis of Moment Structures) version 26.0. Maximum likelihood estimation procedures were used since these afford more security in samples that might not present multivariate normality.

The measurement model fits the data well ($X2 = 371.771$, $df = 179$, $p < 0.001$; $X2/df = 2.077$; $IFI = 0.96$; $TLI = 0.95$; $CFI = 0.96$; $RMSEA = 0.072$).

CFA enables the performance of tests regarding the study constructs' convergent validity, discriminant validity, and reliability. A commonly used method for estimating convergent validity examines the factor loadings of the measured variables [49]. Factor loadings greater than 0.5 are considered very significant [50]. Also, we used the AVE to contrast convergent validity. Fornell and Larcker (1981) suggested that adequately convergent valid measures should contain less than 50% error variance (AVE should be 0.5 or above) [88]. Convergent validity was achieved in this study because all the factor loadings exceeded 0.5 and all AVEs were greater than 0.5. Next, CFA was used to assess discriminant validity. If the AVE is larger than the squared correlation between any two constructs, the discriminant validity of the constructs is supported [51].

The composite reliability (CR) for each construct was generated from the CFA to assess reliability. The CR of each scale must exceed the 0.7 thresholds [52]. Table 2 shows that all the composite reliability coefficients, larger than 0.9, are excellent except for the variable loyalty (0.87). Cronbach's alpha indicator was also used to assess the initial reliability of the scales, considering a minimum value of 0.7 [53]. As shown in Table 2, coefficient alpha values are all over 0.9, exhibiting high reliability, except for the variable loyalty (0.87). Table 2 also shows the AVE for each construct, and a correlation matrix of constructs is also shown. In Table 3, we can see the standardized loadings and t-values of all scale items.

Table 2. Factor Correlation matrix and measurement information

Construct	CR	AVE	X_1	X_2	X_3	X_4	X_5
Internet Banking (X_1)	.93	.77	*.93*				
Interactivity (X_2)	.90	.68	.81	*.90*			
E-Service Quality (X_3)	.92	.71	.87	.86	*.92*		
E-Satisfaction (X_4)	.95	.81	.68	.68	.67	*.95*	
E-Loyalty (X_5)	.87	.69	.81	.81	.77	.75	*.87*

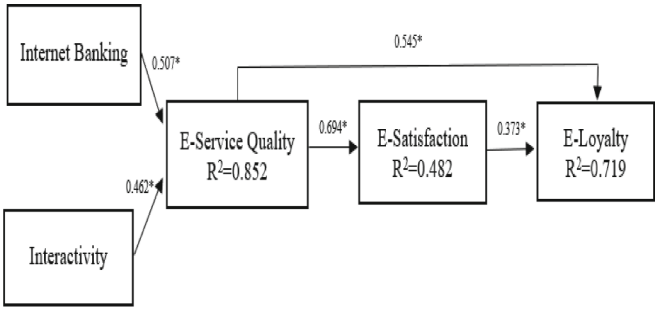
Note: In diagonal entries (italic) are Cronbach's alpha coefficients; AVE, average variance extracted; CR, composite reliability.

Table 3. Measures, standardized parameter estimates results and measurement model t values

Measures	Standardized Loadings	t-Value
Internet Banking		
INTB1	0.877	15.797
INTB2	0.900	16.515
INTB3	0.861	15.319
INTB4	0.881	15.909
Interactivity		
INTE1	0.867	15.373
INTE2	0.826	14.235
INTE3	0.743	12.180
INTE4	0.867	15.354
E-Service Quality		
SQUA1	0.896	16.396
SQUA2	0.923	17.270
SQUA3	0.841	14.790
SQUA4	0.745	12.358
SQUA5	0.781	13.209
E-Satisfaction		
SATI1	0.879	15.961
SATI2	0.855	15.245
SATI3	0.950	18.279
SATI4	0.876	15.857
SATI5	0.927	17.488
E-Loyalty		
LOYA1	0.837	14.350
LOYA2	0.774	12.779
LOYA3	0.871	15.275

4.2 Structural Model

The structural model, depicted in Fig. 2, fits the data well (X2 = 400.966, df = 183, p < 0.001; X2/df = 2.191; IFI = 0.96; TLI = 0.95; CFI = 0.96; RMSEA = 0.076).



R^2=squared multiple correlations; *p<0.001.

Fig. 2. Structural Model

The results in Table 4 show that the five hypotheses proposed in the structural model are all supported.

Table 4. Estimation results of the structural model

Path	Standardized coefficient	t-Value	Hypothesis
Internet Banking →E-Service Quality	0.507*	6.667	H1 (+): S
Interactivity→E-Service Quality	0.462*	6.035	H2 (+): S
E-Service Quality →E-Satisfaction	0.694*	10.747	H3 (+): S
E-Service Quality→E-Loyalty	0.545*	7.256	H4 (+): S
E-Satisfaction→ E-Loyalty	0.373*	5.192	H5 (+): S

Note: * p<0.001 (one-tail tests).

The variable exerting a more substantial impact on e-service quality is internet banking, followed very closely by interactivity. In turn, e-service quality is a powerful predictor of e-satisfaction. When we analyse the influence of e-service quality and e-satisfaction on e-loyalty, we find that, in the case of e-banking, e-service quality exerts a more potent effect.

Thus, in electronic banking, the quality of the service provided plays a decisive role. Therefore, security of transactions, speed, ease of operation, and confirmation of online transactions are essential features of internet banking. In turn, interactivity, translated into good website navigation, 24-h help, and evaluating suitable products and services, is also crucial for e-service quality to be perceived as positive. All this contributes to the overall service quality of e-banking, which will translate into customer satisfaction with online banking and their loyalty.

However, the analysis of the total effects, direct and indirect, becomes very important, since the study of the direct impact may not be revealing. As shown in Table 5, the Boostrapping technique was used with a sample of 2,000 random observations generated from the original sample and a 95% confidence interval.

Table 5. Standardized direct, indirect and total effects

Paths	Direct effects	Indirect effects	Total effects
Internet Banking→E-Service Quality	0.507**	-	0.507**
Interactivity→E-Service Quality	0.462*	-	0.462*
Internet Banking→E-Satisfaction		0.352*	0.352*
Interactivity→E-Satisfaction		0.321*	0.321*
E-Service Quality→E-Satisfaction	0.694**	-	0.694**
Internet Banking→E-Loyalty		0.408*	0.408*
Interactivity→E-Loyalty		0.372*	0.372*
E-Service Quality→E-Loyalty	0.545**	0.259*	0.804¨*
E-Satisfaction→E-Loyalty	0.373*	-	0.373*

Note: * p≤0.001; ** p≤0.01.

Considering the total effects (direct and indirect), the variable that had the most substantial total effect on e-satisfaction is e-service quality, followed by variables internet banking and interactivity. As for the total impact on e-loyalty, e-service quality stands out not only for its direct effect but also for its indirect effect, since it is also a mediating variable between the two variables that preceded it, interactivity and internet banking, and e-satisfaction and e-loyalty variables, which follow it. The variables of internet banking, interactivity, and satisfaction also significantly impact e-loyalty, although to a lesser extent than the e-service quality variable.

5 Conclusions

Electronic banking involves customers interacting through network technology, whereas traditional banking involves customers in non-website-based settings. However, electronic banking services have unique characteristics that conventional banking services do not possess. For example, e-banking allows customers to carry out various banking

activities electronically at any time and place with low handling costs. In this way, electronic banking reduces operating and fixed costs and helps the bank build better customer relationships [21].

Online services' growth has dramatically changed how customers interact with organizations. The quality of online service is the subject of most research in marketing because of the relationship between cost, customer satisfaction, and customer loyalty [48]. In electronic service environments, website quality as the technological application link is critical to the customers, replacing human interactions [47]. The way customers perceive the service quality of a website-based settings is different from that of traditional services. Thus, investigating the service quality in the internet banking industry is essential [3].

Our research has demonstrated the essential role that overall service quality plays in achieving online banking customer satisfaction and loyalty. Therefore, it is crucial for bank managers to be aware that online banking should strive to provide its customers with excellent service.

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The Digital Presence of Universities: A Case Study on Green Taxation Courses

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Abstract. The international community has adopted the 17 Sustainable Development Goals (SDGs) as part of the 2030 Agenda for Sustainable Development in response to the growing concerns about climate change. SDG 13 on climate action and SDG 4 on quality education are highlighted as key goals, with SDG 13 effectively addressing climate change and its impacts, and SDG 4 ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all.

Hence, the objective of this study is to analyse the promotion and dissemination of courses in the field of green taxation (also referred to in the international literature as environmental taxation, environmental law, environmental policy) and environmental law. This will entail identifying the existing courses in this area and the presence of Higher Education Institutions (HEIs) on social media (also referred to in the international literature as social networks).

In this scope, considering the fundamental role of HEIs in the training of future professionals, this study will enhance the comprehension of green taxation in the educational context. The increasing use of digital platforms makes it necessary to analyse the digital presence of HEI on social media in other to promote the teaching of subjects such as green taxation, environmental law and sustainability.

The researchers analysed information from the websites of the top 30 universities in the Shanghai Ranking and analysed existing courses in the field of green taxation and environmental law. Also identified are the top five social media most commonly used for promoting and communicating between students and intuitions.

Keywords: Green Taxation · Green Tax Incentives · Digital Presence · Universities · Social Media

1 Introduction

Since 2015 (although the Conference of the Parties (COP) was originally held in Germany in 1995, this year's Conference was considered a major event), with the Paris Agreement, the United Nations (UN) has recognized the need to respond to the threat

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of climate change, which is a concern for all of humanity. It is important to ensure the integrity of all ecosystems, including oceans, protect biodiversity, and prioritize education, training, public access to information, and cooperation at all levels to address climate change. In this context, they share a common objective, which is to limit the global temperature rise to two degrees Celsius below pre-industrial levels and a gradual reduction in the use of fossil fuels for several decades [1]. One of the issues that has been raised is the increase in CO2 emissions into the atmosphere as a result of consumption and societal activities, which is considered to be the main contributor to climate change.

To combat this problem and its effects on health and the environment, the use of renewable energy sources must be a priority. The literature suggests [2] that achieving this goal requires the adoption of environmental policies by governments, i.e., governments have a responsibility to promote policies that protect society and encourage behavioural change using available instruments, such as green taxation. It is suggested that governments not only introduce green taxes but also co-ordinate them with related benefits and incentives to encourage sustainable behaviour and protect the environment.

Since 2015, the international community adopted the 2030 Agenda for Sustainable Development, which includes 17 SDGs to end poverty, promote equity and protect the planet. Therefore, the UN has placed education at the centre of promoting and achieving the SDGs, this is, ensuring that all students acquire the necessary knowledge and skills to promote the transition to sustainability and ensure a sustainable and equitable society [3]. Due to the transdisciplinary nature of sustainability, it must be a part of all areas of education and professional life. Hence, HEIs have a crucial and privileged role in promoting sustainability literacy, which is essential for engaging students with environmental and climatic action issues and developing their sense of responsibility for the common good.

An effective way for HEIs to achieve this is to integrate sustainability across their undergraduate and postgraduate curricula [4]. Digital technology is an integral part of young people's lives from birth. Despite this, some authors [5, 6] argue that it is clear that students are not adequately prepared for the technology-rich society they will encounter. As a result, HEI and educators must undergo a significant digital transformation to meet the needs of the current generations and the fully digital world they will inhabit [6]. This transformation and evolution in the academic sphere will lead to improved communication between students and lecturers in higher education. Therefore, social media platforms such as Facebook, Instagram, Snapchat, YouTube and WhatsApp, among others, are integrated into the learning process to complement it and improve communication and interaction between students and teachers [7].

In this scope, this study evaluated the digital presence of HEI through social media to engage and interact with young people and to disseminate information about courses on green taxation and/or environmental law. To this end, the authors carried out an analysis to find out whether the top 30 universities in the Shanghai Ranking were using social media and, if so, which platforms they were using. This study is structured in five sections. Following this introduction, section two is devoted to a review of the literature. Section three describes the research methodology, while section four presents and analyses the results. In the fifth section, the main conclusions of the study are presented.

2 Literature Review

2.1 Green Taxation

The main source of environmental degradation is caused by human activities that increase CO2 emissions. Air pollution rules and emissions controls have an important impact, because pollutants in the air damage the weather, the way plants and animals work, ecosystems, and people's property (crops, buildings). Therefore, to address the issue of environmental degradation caused by the industrial sector (the sector that exhibited the most significant growth in CO2 emissions), environmental taxes such as carbon tax have been suggested as policy tools. In the scope of pollution strategies, "environmental taxation is indispensable as it discourages the proliferation of pollution-intensive activities and compels enterprises to ensure environmental sustainability" [2].

Green taxes are considered an important policy tool, they can take the form of taxes on carbon-intensive businesses, taxes on energy use, or subsidies for renewable energy technologies. The aim is to reduce the burden on natural resources. However, the implementation of higher taxes, including dual taxes such as corporate tax rates and environmental taxes, may increase a company's production expenses and could potentially discourage the adoption of cleaner technology [2].

To implement environmental taxation and green tax reform, insights from behavioural economics should be utilized. This involves ensuring that individuals accept a budget-neutral tax reform, where the value of what they receive is higher than the value of what they sacrifice – this is based on the endowment effect phenomenon [3].

Environmental Taxation and Theoretical Considerations: Environmental taxes are defined by the Organisation for Economic Co-operation and Development (OECD) as government charges levied on private or corporate individuals to discourage and limit harmful practices that contribute to environmental degradation.

Studies reveal that the environmental tax rate "discourages the pollution-intensive activities of industrial activities and compels corporate managers to adopt modern technology and modification outdated production systems and reduces the overall quantity of pollution emissions" [8]. On the other side, the corporate statutory tax rate can cause financial issues that reduce the capacity of enterprises to explore environmental technologies, which have a direct impact on pollution emissions.

Therefore, the concept of Load Capacity Factor (LCF) has emerged in the literature [10]. LCF suggests that there is a limit to the amount of resources that a given population in the natural environment can sustain, often referred to as the "carrying capacity" of the environment. In essence, the environment becomes degraded, with negative impacts on both the natural environment and human society, when there is a demand for resources that exceeds the environment's carrying capacity [10].

This theory mentioned that the government should promote sustainable practices for the long term, motivating policymakers and businesses to collaborate and develop sustainable practices to ensure resilience and environmental sustainability. However, pollution resulting from industrial activities is an example of a negative externally imposed on society, as affected individuals have no right to claim any compensation for the damage suffered. Hence, the approach of social practices is combined with the theories of environmental economics, specifically Pigou's theory which is considered the basis of

environmental taxation, and Coase's theory. Arthur C. Pigou developed the concept of Pigouvian taxation, which involves using taxes to address external factors. This environmental tax is equal to the marginal damage at the efficient pollution level, maximizing allocative efficiency and welfare.

The assumption is that economic agents act rationally according to their individual preferences, maximizing their utility [9]. In contrast, the Coase theorem suggests that this scenario can result in an equally efficient outcome as compared to an individual's property rights. In theory, the involved parties could negotiate and agree on compensation for the damage based on the individual's or polluter's property rights, rendering government intervention unnecessary [9]. In practice, the large number of individuals and polluters, as well as the costs of negotiations, prevent an optimal outcome of private negotiations.

Therefore, government regulation is needed, such as taxation and regulatory policies, to aim for environmental improvement. This is called environmental taxes [9]. However, it is often difficult to apply traditional decision-making theories in ecological contexts due to limited knowledge of cause-and-effect relationships and the inevitable political compromises that result in incremental changes rather than structural reform. This is further complicated by the complex and long-term nature of ecological issues and their social implications.

Green Tax Incentives: Tax rates can be differentiated. In some cases, certain products, processes, or groups of taxpayers may be granted a lower tax rate or be exempt from the tax. The tax can be implemented at a specific moment in time or in multiple phases, with the tax rate being raised or reduced in each phase [9]. On the other hand, according to several authors [11, 12], in addition to green taxes to mitigate environmental changes, governments can support environmentally friendly activities through economic incentives.

As emphasised by [13], the crucial role of utilizing effective financial and fiscal instruments, such as finance and taxation, is to achieve a balanced implementation of sustainable development (SD). Furthermore, to achieve this goal, we must not only act as an ordering or regulatory authority but also take a coordinated approach that includes sanctions, incentives or stimuli to encourage behaviour that is in line with SD. Thus, in particular, companies are encouraged to acquire new environmentally friendly assets through green tax incentives, which are seen as an important tool for promoting environmental protection and SD, rather than simply as a means of reducing tax burden [11].

Portugal's programme to promote the scrappage of passenger vehicles is an excellent example of a green incentive whereby it aims to improve the environment by encouraging the purchase of new or used electric passenger vehicles (up to four years)[1] [14]. Similarly, the United States government has implemented tax incentives aimed at improving the environment. One of these incentives is a tax credit for the purchase of a qualified electric vehicle, which can be claimed on the purchaser's income tax return for the year of purchase [15].

[1] Approved by article no. 281 of Law No. 82/2023, of December 29th (which approves the 2024 State Budget).

2.2 Higher Education Institutions

The HEIs, through learning, innovation, and research can support the progress of civil society. Many institutes are implementing sustainability practices and projects to address climate change [16]. As the SDGs are designed to be universally applicable, education is widely recognised as a key component of any sustainable development strategy. Given the main activity of HEIs, they can play a critical role in the achievement of the SDGs through the promotion of awareness and the dissemination of knowledge and values to businesses and citizens [17].

No longer a privilege reserved for a few, higher education is now a prerequisite for success, for providing for one's family and for tackling the world's most pressing issues [6]. Additionally, HEIs face the challenge of educating professionals in a balanced way to promote organisational development, while meeting current needs and considering prospects for SD, this means that students need to be trained to think critically and autonomously.

As suggested by the literature [18], HEIs should educate current students, future professionals and entrepreneurs on the "Triple Bottom Line", which includes the environment, society and economy. Thus, the authors argue that issues related to SD, such as ethics, corporate social responsibility, sustainability, environmental law and green taxation, should be integrated into the curricula of HEIs. On the other hand, according to the literature [19], students are becoming more discerning when selecting universities and tend to favour those with higher visibility.

Hence, a positive institutional image, which allows students to perceive their specialisation, reliability and quality, is becoming increasingly important for the growth of universities.

2.3 Digital Presence

The rapid development of digital technologies has led to significant changes in society and the economy. However, for society to function properly in this new digital environment, institutions must be able to respond effectively to the demands and needs of citizens [20]. It is generally accepted that the Internet has become a popular platform for access to information and communication. online platforms are now an integral part of many aspects of daily life and digitalisation has become ubiquitous in modern society. The opportunities offered by digital technologies have led to the development of an understanding of implicit technologies, and their perception and use [6].

Studies have highlighted the importance of institutions having a digital presence, not only as a reputational strategy but also as a means of connecting with society [20]. From education to employment, the digital sphere plays a significant role in shaping our experiences [21].

According to several authors [22, 23], HEIs are actively using digital platforms to present their content and the profiles of their lecturers and administrators, building a global digital presence for the institution.

Social Media: Social media are defined as a group of individuals and organisations linked by social relationships who interact to share resources and communicate. This

interaction takes place in the context of a virtual community in which members can share information and form groups for learning [24]. The increase in the use of the internet has led to a corresponding increase in the amount of content that is available online. Commonly referred to as "digital natives", students regularly use the internet and technology to communicate as well as to stay informed and learn [21].

Hence, HEIs need to develop an active profile on social networking sites to disseminate information widely and encourage interaction and engagement with users. On the other hand, the type of presence and level of activity chosen will ultimately define the HEI posting strategy, which will certainly influence the level of engagement achieved with the target audience [22]. Thus, HEI aims to increase its public visibility and establish direct links with students, alumni, journalists and businesses through the use of social media platforms [25].

Furthermore, social media aim to facilitate student's learning beyond the classroom through several tools, including Facebook, YouTube, X (formerly known as Twitter), Instagram, and WhatsApp, among others [24]. The purpose of this study is to investigate the digital presence of HEIs by examining the information available on their websites regarding the use of social media.

3 Methodology

This study used a qualitative exploratory and descriptive design, with the collection of data on the websites of the top 30 universities from the Shanghai Ranking. The Shanghai Ranking, also known as the Academic Ranking of World Universities (ARWU), is one of the most respected university ranking systems, according to several authors [26, 27]. Based on available information from the top 30 HEIs, the authors compiled a database of the courses in the field of green taxation and environmental law, as well as several social media used by them, using Microsoft Excel to accumulate, sort, visualise and process it. The present study did not involve human participants, but the authors addressed ethical concerns with confidence to ensure the ethical integrity of the study.

In addition, this study was carried out between 1 November 2023 and 15 February 2024.

4 Findings

Following the objectives of the present study, it was found that 28 out of the 30 universities under study had introduced courses in the field of green taxation. It was not possible to obtain information on courses related to green taxation at Tsinghua University and, in particular, the University of California, San Francisco does not appear to offer such courses (as stated on the university's website, the institution's mission is to provide education and research exclusively related to the health sciences).

Upon analysing the obtained data, it is evident that green taxation is a multidisciplinary field. The majority of the courses – 43% - are offered in the field of law. However, there are also courses in other fields such as economics, environmental sciences and political studies.

Table 1. HEIs' Courses on Green Taxation

University	Courses (scope of green taxation)	Subjects under study		
		Sustainability	Environmental Law	Green Taxation
Harvard University	Law and Government	x	x	
Stanford University	Environmental Law & Policy	x	x	
Massachusetts Institute of Technology (MIT)	Environment & Sustainability	x	x	
University of Cambridge	Environmental Policy	x	x	
University of California, Berkeley	Environmental Economics and Policy	x	x	
Princeton University	Environmental Studies	x	x	
University of Oxford	Environmental Law	x	x	
Columbia University	Earth and Environmental Sciences	x	x	
California Institute of Technology	Law and Economics	x	x	
University of Chicago	Environmental Law - Climate Change and the Law	x	x	
Yale University	Environmental Law and Policy	x	x	x
Cornell University	Study International Law	x	x	
University of California, Los Angeles	Earth and Environmental Science	x	x	
University of Pennsylvania	Sustainability and Environmental Management	x	x	

(*continued*)

Table 1. (*continued*)

University	Courses (scope of green taxation)	Subjects under study		
		Sustainability	Environmental Law	Green Taxation
Paris-Saclay University	Environmental Law and Public Policy	x	x	
Johns Hopkins University	Environmental Planning and Management	x	x	
University College London	Law	x	x	
University of Washington	Environment	x	x	
University of California, San Diego	Environmental Studies	x	x	
ETH Zurich	Environmental Sciences	x	x	x
University of California, San Francisco	*No Green Taxation Course*			
Tsinghua University	*No Data Access*			
Imperial College London	Environmental Technology	x	x	
University of Toronto	Environmental Science	x	x	
Washington University in St. Louis	Environmental Analysis	x		
University of Michigan-Ann Arbor	Environmental Law and Sustainability Clinic	x	x	
The University of Tokyo	Natural Environmental Studies	x	x	

(*continued*)

Table 1. (*continued*)

University	Courses (scope of green taxation)	Subjects under study		
		Sustainability	Environmental Law	Green Taxation
New York University	Environmental and Energy Law	x	x	
Peking University	Law	x	x	
Northwestern University	Law Studies - General or Interdisciplinary	x	x	

Source: Data adapted from the websites of the top 30 universities in the Shanghai Ranking. Data extracted on 15 Feb 2024. https://www.shanghairanking.com/rankings/arwu/2023

Table 2. Digital presence of HEI on TOP 5 Social Media

University	Country	TOP 5 Social Media				
		Facebook	X	You Tube	Instagram	Linked In
Harvard University	USA	x	x	x	x	
Stanford University	USA	x	x	x	x	x
Massachusetts Institute of Technology (MIT)	USA	x	x	x	x	
University of Cambridge	UK	x	x	x	x	x
University of California, Berkeley	USA	x	x	x	x	
Princeton University	USA	x	x	x	x	x
University of Oxford	UK	x	x	x	x	x
Columbia University	USA	x	x	x	x	
California Institute of Technology	USA	x	x	x	x	
University of Chicago	USA	x	x	x	x	x
Yale University	USA	x	x	x	x	x
Cornell University	USA	x	x	x	x	
University of California, Los Angeles	USA	x	x	x	x	x
University of Pennsylvania	USA	x	x	x	x	x
Paris-Saclay University	France	x	x	x	x	x
Johns Hopkins University	USA	x	x	x	x	x
University College London	UK	x	x	x	x	

(*continued*)

Table 2. (*continued*)

University	Country	TOP 5 Social Media				
		Facebook	X	You Tube	Instagram	Linked In
University of Washington	USA	x	x	x	x	x
University of California, San Diego	USA	x	x		x	x
ETH Zurich	Switzerland	x	x	x	x	x
University of California, San Francisco	USA	x	x	x	x	
Tsinghua University	China	x	x	x	x	x
Imperial College London	UK	x	x	x	x	x
University of Toronto	Canada	x	x	x	x	x
Washington University in St. Louis	USA	x		x	x	
University of Michigan-Ann Arbor	USA	x	x	x	x	x
The University of Tokyo	Japan	x	x	x	x	x
New York University	USA	x	x	x	x	x
Peking University	China	x	x	x	x	x
Northwestern University	USA	x	x	x	x	

Source: Data adapted from the websites of the top 30 universities in the Shanghai Ranking. Data extracted on 15 Feb 2024. https://www.shanghairanking.com/rankings/arwu/2023

Table 1 shows the courses offered in the field of green taxation at the universities in the top 30 from the Shanghai Ranking. The research was conducted using the keywords "environmental law", "green taxation" and "sustainability" in order to identify courses related to environmental taxation. Table 1 shows that of the 30 universities analysed (in the scope of green taxation), 28 offer subject courses in sustainability, 27 in environmental law, and only two in green taxation. It can be assumed that green tax courses are scarcer than expected, considering the involvement of HEI's in the fight against climate change, and given the scope of the HEI's programme.

The next step was to find out how universities advertise their courses. Analysing the information contained on the websites of the top 30 universities from the Shanghai Ranking, a total of 21 social media platforms were identified. Table 2 shows the digital presence of each university through the top five social media, based on the analysis of the authors. Table 2 reveals that the top five social media of the most used among the 30 universities, which are Facebook, X, YouTube, Instagram and LinkedIn.

Furthermore, the results show that 20 universities in the United States of America (USA), four in the United Kingdom (UK) and two in China use all the social media in the top five. Additionally, there has been an increase in the use of the social media TikTok, which is now used at nine of the universities in the study. Finally, social media such as Podcasts, EdX, Pinterest, Space Bilibili, Threads, GIPHY, The Conversation

and Coursera were presented in only one of the 30 universities. Universities using these social media were not analysed in this study.

5 Conclusions

This study aims to analyse the digital presence of the top 30 universities from the Shanghai Ranking, focusing on their presence on social media, which is increasingly being used to communicate, promote the image of universities and highlight their specialities, particularly in courses related to green taxation and environmental law. As this study focuses on HEIs, it is expected that students will become more autonomous in their learning process, therefore the provision of information and communication tools plays a fundamental role, confirming the results obtained in previous studies [28].

In this sense, the authors confirm the existence of these tools, namely the existence of information on websites and the use of Facebook and Instagram by all 28 universities, which aim to allow students to participate in debates, news and relevant events on green taxation and related topics such as sustainability and environmental law. Once more, consistent with previous studies [24], the authors stated that a university's digital presence is critical to its growth, as potential students, investors and others look for information online. Social media is also being used for educational purposes, allowing students to continue their studies, communicate and share learning outside the classroom.

In this scope, the authors emphasise that education policies should encourage collaboration between HEIs and parents to improve the way they advise and follow up on their student's digital education. Finally, the authors highlight the fundamental role of HEIs in the training of future professionals with decision-making and recommend that topics such as green taxation, environmental law and sustainability should be strongly disseminated to future students within the framework of the SDGs to combat climate change, which can be done through web platforms.

Therefore, the objective of this study is to contribute to the analysis of the integration and dissemination of green taxation and environmental law in HEIs. In particular, the study aims to highlight the relevance of teaching sustainable development and environmental protection, while also considering HEIs digital presence.

Future research could explore several key areas, such as subject area of each course, the level of each course, the duration of each course, etc. Firstly, to investigate whether social media promotes the sharing of reflections on courses, and secondly, to critically evaluate the impact of green taxation courses on learning experiences and their practical application. Thirdly, in light of the significance of the conducted research, it would also be beneficial to further investigate the link between the courses, their promotion on social media and the impact this has on students. Additionally, it would be useful to analyse the methods employed to disseminate information about each course, across the several social media under review.

There are limitations to this study that could be addressed in future research. For instance, the sample size was relatively small, although it was sufficient to answer the subject under study. Also, it will be important to approach the eventual violation of the "capacity of contribute" which is not consider in green taxes. This is the most important principle of taxation, which must not be forgotten as a component of education.

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Erasmus+ Projects and Science Communication in the Digital Era: The CARE Project Dissemination Plan

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Abstract. Science Communication through research projects is one of the major knowledge dissemination tools of Higher Education Institutions. These projects, normally implemented by international consortia and funded by the European Commission, assist and guide in the use of scientific knowledge by citizens. Although science is generally received as something positive, trust is a main variable in the way scientific work is assessed by the general population. If results of research can contribute to a change in behavior and the societal impact is visible, credibility towards science is validated. This paper focuses on the Dissemination Plan of an ERASMUS+ project targeted to responsible consumption, CARE. It details its aims and objectives, how they were accomplished, the type and resources used, and examples of reporting tools to reach the different targets. To create interaction with and impact the audiences, outputs were designed to maximize practicality, facilitating the evaluation of their effectiveness, evident in the test and validation stage. In addition, the diverse expertise and commitment of stakeholders and the complementary strategies implemented along the project's lifetime, contributed to reinforce the positive perceptions of Science Communication, namely through digital means, increasing public engagement and building trust in relation to scientists and academia.

Keywords: Science Communication · ERASMUS + · Projects · Dissemination Plan; Education

1 Introduction

1.1 Science Communication in Education 5.0

Science Communication (SC) is a concept inherent to the existence of education itself, especially in Higher Education Institutions (HEIs). Science has been from immemorial times a propelling agent for renewal, acting as a driver at all levels of knowledge. Communicating science in a 5.0 educational paradigm is a challenge every HEI needs to face.

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The way science and society interact suffered profound changes, especially in recent years, due to the emergence of a digital era, where science, as it was traditionally conceived, lost its podium to other actors and communicators (e.g., [1]). The dissemination of scientific knowledge is mainly achieved through the communication of research results. But not only. Practical outputs of research projects play a fundamental role as mediators of knowledge dissemination, and HEIs are privileged ecosystems to support and promote such initiatives and create new opportunities for all involved in the process. These projects, normally implemented by international consortia and funded by the European Commission and other relevant institutional or private stakeholders, assist and guide in the use of scientific knowledge by citizens, increasing public engagement with science and building trust in relation to scientists and academia.

As observed by [2], although science is generally received as something positive, trust is a main variable in the way scientific work is assessed by the general population. If results of research can contribute to a change in behavior and the societal impact is visible, credibility towards science is validated [3], not only in terms of relevance, but also in the practicality of its achievements, particularly when partnerships with different stakeholders take place.

In this regard, [4] enumerated five areas in that SC can be rated, from the responsibility of being funded by public resources and therefore ethically obliged to communicate results to the public (accountability), to provide knowledge of a practical value (pragmatism), acting as mediators for debate in public spheres (assistance to democratic and normative goals), conveyance of educational values (culture), and institutional promotion (reputation). This last aspect is further exploited by [1], when reflecting upon the relationship between society, science and the media.

Studies indicate that the intentions of scientists when communicating science can sometimes be inconsistent, focusing more on how they perceive their impact on audiences and not so much on how audiences perceive improvements from SC. In other words, and as observed by [5], there is more concern with the skills and the production of content rather than on how communication can impact the recipients. New approaches to teaching and learning are taking place and will revolutionize the way we apprehend knowledge, leading to a 'supersmart society', as stated by [6].

This ability of SC to change the world in a positive way relates to the advantage of congregating trainers, experts, researchers, and supervisors in HEIs, added by the fact that institutional partnerships and close interaction with other relevant stakeholders is mandatory to achieve dissemination results. Whether in the founding text of [7] or in the recent research of [8], one crucial question continues to be the public understanding of science.

Dissemination Plans (DP) of international projects are, in this context, a privileged way to communicate science to the public and other audiences, and their practical objectives constitute a powerful tool to enhance engagement, enabling learners to have access to content at their own pace, thus becoming themselves agents in the process.

1.2 Science Communication Within ERASMUS+ Projects

Communicating projects and their results is crucial to ensure impact at different levels [9]. The DP of an ERASMUS+ project is a vital part of the application, since the evaluation of

these projects is also substantially based on criteria that guarantee the maximization of the project's results and continue to ensure its educational impact in a digital environment.

This work focuses on the case of an ERASMUS+ project, included in Key Action 2: Cooperation among Organizations and Institutions. These projects aim to have a positive impact on society and contribute to bringing the knowledge resulting from research to the community, may it be at a local, regional, national, or European level [10]. In the field of adult education, these projects prioritize "availability of high quality, flexible and recognized learning for adults" [10] (p.172), thus incentivizing not only the development of flexible learning spaces but also offering wide-learning opportunities to all.

The assessment of the impact of these projects is based on the potential for free use of the project results in wider communities (local, regional, national, and European), not only during the life of the project, but also after its conclusion [10].

On the one hand, the concept associated to the DP encompasses all activities that each partner, individually, must carry out to reach target groups (vertical dimension). On the other hand, the concept includes all activities and instruments that can strengthen communication between all partners and transversal dissemination (horizontal dimension) [11].

The purpose of this work is to present the implementation of SC initiatives within an ERASMUS+ project.

2 Materials and Methods

2.1 CARE, a Project on Sustainability Geared Towards New Educational Paradigms

With a clear orientation towards promoting responsible consumption models, the United Nations (UN) and the European Union (EU) established the Sustainable Development Goals (SDGs) that define priorities and common objectives for a global sustainable development, to be achieved by 2030. Among them, the SDG12 (whose motto is Responsible Consumption and Production), aims to boost the world's economy towards a more sustainable model. And it is precisely to comply with SDG12 that the international CARE project was designed, with the aim of raising awareness and sensitizing consumers towards a more responsible consumption.

The project, implemented from 1 December 2021 to 28 February 2024, was coordinated by the University of Malaga, and brought together seven partners from four European countries. An Open Educational Resources (OER) platform, available in four languages (English, Spanish, Italian and Portuguese) was generated to integrate all project results [12].

2.2 Dissemination as a Paramount Action

To ensure the impact of the project and the wider recognition of its results, planning the dissemination of project activities is a paramount action. In this sense, a well-structured DP is an effective instrument that guides the entire process, receiving special attention during the evaluation of the project application [10].

To achieve this, the DP proposed for CARE used different strategies, methodologies, and tools to raise awareness about the project objectives, to provide high-quality information, to aid in the transferability of results and to convince ultimate consumers and decision-makers to apply them. The DP works in parallel with all phases of the project, being adjusted according to the activities of each partner of the consortium. To guide the plan, the ERASMUS+ application strongly recommends answering seven questions: 1. Why disseminate; 2. What to disseminate; 3. Who is the target; 4. Who is responsible; 5. When to disseminate; 6. How to disseminate; and 7. How to evaluate dissemination [10].

The choice of different approaches is based on each partner's experience and appropriate resources are allocated to implement activities. Internal dissemination (within the project consortium and direct beneficiaries) and external dissemination (with other relevant stakeholders) are encouraged. Different reporting tools may be used to record all the activities performed. The guidelines for a good DP also recommend applicants to take into consideration not only the communication objectives and the target groups chosen, but also the channels to reach them and the timing when the different activities should take place [8].

One aspect of CARE DP was related to the opportunity some consortia members had to directly target end users, namely university students. Two universities were involved in the implementation of the project and capitalized on their educational environment to develop activities inside and outside class to engage students in sustainable practices.

As an example, under-graduate students of marketing at the University of Aveiro prepared and pitched communication plans to external entities in one of the four areas of the project–transportation, energy, food and clothing. This task demanded an entire semester of work, leading to deep research in sustainability topics, to the involvement of students in broader social issues and to the dissemination of CARE objectives to peers. These practices corroborate the important role of SC in promoting knowledge dissemination and building trust in scientific research.

3 Results

This section presents the main results achieved under the SC initiatives of the CARE project.

3.1 Aims and Objectives of the Dissemination Plan for CARE

At the very beginning of the DP for CARE, aims and objectives of the dissemination are introduced. Within this topic, Table 1 displays the answers to the seven questions that guided each dissemination strategy. To accommodate the aims and objectives for the DP and explore internal and external dissemination, the consortium resorted to diverse activities to spread the project outcomes at local, regional, national, and European levels as seen in Table 2.

To guarantee the visibility of the project and its sustainability, the DP included the identification of different target groups to be considered in internal and external dissemination (Table 3). As can be observed, to bring the project results to the target groups, the consortium used a series of methods and means.

3.2 Dissemination Reporting Tools

As a basis for recording the different lines of action, the consortium produced a disclosure reporting tool, which contains spreadsheets relating to online dissemination, offline dissemination, stakeholders and policy makers, internal communications, and other indicators that each partner may consider necessary. These tools allow for a permanent updated record of all activities carried out by each partner, providing a set of real data that helps to monitor the ones that were implemented.

As an example, Table 4 presents data regarding stakeholders and policy makers. A total of 340 people were reached. Another example, presented in Table 5, displays the activities carried out by one of the partners regarding offline dissemination. A total of people 1.234 were reached. As another example of another partner, this time regarding online dissemination, Table 6 presents some figures. At the moment data was consulted, more than 13.810 people were reached. Regarding communication, Table 7 also provides some examples.

Additionally, CARE made use of an OER platform, created and planned to house content materials, namely the implementation of 40 micro-courses within two levels (basic and advanced) for 4 different areas (responsible food, responsible mobility, responsible clothing, and responsible use of resources) and presented in 4 languages (English, Spanish, Italian, and Portuguese). The test and validation of these courses was made by online, face-to-face and hybrid modes (Table 8).

The previous results show part of the audiences reached within the DP for CARE, over the project lifetime till the moment of this study. However, the dissemination of project activities is expected to continue at least two years beyond the project lifetime. One additional aspect should be highlighted when considering the impact of project results, namely the fact that university students had the chance of being directly involved in the project, not only in preparing class tasks, but also in collaborating in the test and validation phase. These activities bridged target groups with project outputs, justifying CARE's main purpose, with students being themselves promoters of science.

4 Discussion

HEIs and other educational actors must be prepared for profound changes in their ecosystem in the years to come. This reframing includes maximizing inter-institutional collaboration and anticipating teaching and learning strategies capable of capturing and retaining audiences. In this regard, ERASMUS+ and other research projects are valuable means to reach this end, while generating, communicating, and disseminating knowledge through science. Their preparation requires a great deal of detail regarding implementation and outputs, and each stage of the project is carefully outlined in such a way that all stakeholders have the necessary means to reach the target audience and impact them successfully.

In fact, the impact at societal level is one of the primary goals, where the way science is communicated and the way citizens perceive that communication should converge [1, 5]. This interaction between science and society may adopt diverse and complementary methods and strategies, especially today, where SC can take advantage of digital channels to increase engagement and allow for a much closer relationship with the public. To

accomplish this objective, all stakeholders involved in the DP should be aligned and motivated in the implementation of offline and online activities, as the ones displayed for CARE, whether inside or outside the academia, providing a valuable help in the use of scientific knowledge by the public.

The more practical the results, the higher the engagement, turning the experience into something meaningful and experiential. However, the scientific validation of those results should be clear to audiences, thus placing a strong and important role in the communicators' credibility [2]. The variables enumerated by [4] are reflected in the profuseness of activities and the high level of commitment of the consortium in the CARE DP, visibly implemented online and offline, reaching different types of target groups and therefore augmenting trust in SC and its mediators.

The fact that CARE was focused on important areas of responsible consumption, together with the composition of the consortium (integrating HEIs, other relevant actors in education, trainers, practitioners, and official institutions) contributed to fostering trust in the set of courses made available through the OER platform, a tool of easy access to all interested in this subject. The Test & Validation stage confirmed the pertinence of the contents, assisted by a well-planned DP. This stage is crucial to understand the level of engagement with SC, thus corroborating the observations of [7] and [8]. Projects such as ERASMUS+ are significant contributions to foster a society 5.0, helping to bridge the gap between scientific knowledge and citizens, and CARE constitutes a valuable example of how SC can impact society positively.

5 Limitations

Projects that encompass several domains of social behavior, as the case of CARE, have always the potential to go further. To congregate more associated partners from different locations within each country – since, for example, the consumption habits differ from the coastal area to inland regions – or to integrate more specific institution dedicated to each of the topics of the project, are among the limitations to be mentioned. Suggestions for future research include the replication of the project in other countries or regions, namely Northern Europe, to assess citizens' consumption journey.

Table 1. A guide for the DP of CARE

Question	Answer
Why disseminate?	• To tell end users about the project • To contribute to policy development (local, regional, national, European) • To inform and advocate to sponsors and funding bodies • To support and enhance the image of the organization • To increase the impact of the project by extending it to multipliers • To tell commercial organizations that you have a product to sell

(*continued*)

Table 1. (*continued*)

Question	Answer
What to disseminate?	• The project mission or message • The deliverables • The project processes • The methodologies • The European partnership • The European network
Who is the target?	• End-users • Organizations that can help to reach others • Organizations that can enhance the impact of the project in other ways
Who is responsible?	All partners are responsible for their national dissemination plans, including the involvement of stakeholders
When to disseminate?	The project proposal presents an initial time schedule regarding the completion of project results and dissemination instruments; dissemination is an ongoing activity, and partners should provide news and information about the CARE project on any activity, result and event related to the project
How to disseminate?	The project proposal already gives specific instruments to be used for dissemination activities such as newsletters, project website and dissemination events in each partner country; furthermore, the project includes specific activities targeted to raise awareness and to involve and engage the target group and stakeholders such as local discussion groups; within this work package, additional instruments were produced, such as flyers; each partner also presented individual instruments in the national dissemination plans that show great promise for the implementation of the dissemination and exploitation phases
How to evaluate dissemination?	A very useful way of evaluating the dissemination activities is the documentation of all activities by each partner; this documentation can be in form of lists of participants, presentations, agendas, meeting, minutes, pictures, and copies of documents such as emails, articles, or newsletters; the documentation should be based on the use of quantitative and qualitative indicators; a detailed explanation on how using it is at the end of this document

Table 2. Type of dissemination and resources used

Type of dissemination	Resources used
Direct contact	Mailing lists, social media campaigns, leaflets/brochures/posters, in the various languages of the project
Dissemination events	Meetings, workshops, round tables, speeches, courses, seminars, conferences, both of own organization and organizations to which they are invited by third parties
Publications	Scientific, academic, and general information reports and articles (depending on partners), press releases, interviews, reports, and others
Participation in special events	Congresses and conventions of consumption, CSR, and others
Social media	TV, radio and digital media, web radio speech, online TV participation, social networks, websites, and newsletters

Table 3. Dissemination means

Dissemination	The results will be shared with
Internal dissemination	• Authorities and technical staff can use the results in their training and institutional dissemination programs • University professors and their own trainers, who would be users and prescribers in their training activities and networks, namely by conveying the project to students and performing project-related activities in class • Non-academic staff, administrators, collaborators, technicians, and service personnel, who would be direct users through internal training programs, and broadcasters in their personal networks • Traditional university students (e.g., bachelor's, master's, and doctoral degrees), students from other courses (e.g., senior school, refresher, and specialization courses) • Users and clients of complementary and transversal activities (e.g., Healthy AMU, Wellness Days, client companies)

(*continued*)

Table 3. (*continued*)

Dissemination	The results will be shared with
External dissemination	• High school students, VET, universities, and others, of the usual networks with which the partners relate • Researchers and centers related to responsible consumption and the production of sustainable goods and services, to the culture and sociology of consumption • Consumer associations, CSR, environmentalists, social/circular economy, trade unions • Adults immersed in training activities, awareness, and volunteering through the associated collaborating entities • General population interested in improving their consumption habits • Networks and federations to which the partners belong • Authorities responsible for formulating policies, political actors who can influence the design and implementation of educational, consumer, awareness-raising, and others • Prescribers, social and digital influencers, and relevant people whose opinions and advice are appreciated by target audience and general population • General public, consumer population

Table 4. Stakeholders/Policy makers (Partner 7)

Stakeholder/Policy maker	Level	People reached
Councillor	Regional/Local	6
Policy Maker	European/National / Regional/Local	43
Other	National	30
Mayor	Local	5
Other	International	256
Total		340

Table 5. Offline dissemination (Partner 2)

Action type	Level	Target groups	People reached
Conferences Dissemination events	European/National	End-users	1234

Table 6. Online dissemination - some examples (Partner 4)

Action type	LINK	People reached
Press Release	https://elfarodeceuta.es/sostenibilidad-centra-foro-ciudades-transfronterizas-bpw/	-
Press Release	https://www.canalsur.es/radio/programas/canal-sur-mediodia-malaga/detalle/2894788.html?video=1822812	10000
Mailing List	www.uma.es	-
LinkedIn	https://www.linkedin.com/feed/update/urn:li:activity:6918231548148252672	43
Seminar /Conference	"Foresight, Design and Urban Planning" www.icesco.org	500
Seminar /Conference	Ceuta Open Future	10
Own website	https://www.rsctalent.com	-
Facebook	https://www.facebook.com/rsctalent/posts/pfbid0eVUqy6hjjiqkvxQbsT8dKojKN2JfuTGJT7pjUX9zbcwyLSwiKjgFDvb2pxNUevYrl	407
LinkedIn	https://www.linkedin.com/posts/rociotorresmancera_wwwcareforplaneteu-partners-meeting-on-activity-6999070537909972993-7BE2?utm_source=share&utm_medium=member_desktop	157
LinkedIn	https://www.linkedin.com/feed/update/urn:li:activity:6999070243704696832	47
LinkedIn	https://www.linkedin.com/posts/rociotorresmancera_careforplanet-euprojects-activity-6998208899015139329-6WXy?utm_source=share&utm_medium=member_desktop	339
LinkedIn	https://www.linkedin.com/feed/update/urn:li:activity:6998207389850030082	53
LinkedIn	https://www.linkedin.com/feed/update/urn:li:activity:6980857576833884160	89
LinkedIn	https://www.linkedin.com/posts/rociotorresmancera_fairfood-care-helpfood-activity-6980857625122902016-9K4F?utm_source=share&utm_medium=member_desktop	76
Seminar /Conference	https://congresolatina.net/libro-de-actas/	143
LinkedIn	https://www.linkedin.com/feed/update/urn:li:activity:7061319211905617920	65
LinkedIn	https://www.linkedin.com/feed/update/urn:li:activity:7061336132331945984	23

(*continued*)

Table 6. (*continued*)

Action type	LINK	People reached
LinkedIn	https://www.linkedin.com/feed/update/urn:li:activity:7071847639297703937	42
LinkedIn	https://www.linkedin.com/feed/update/urn:li:activity:7076540325657198592	22
LinkedIn	https://www.linkedin.com/posts/rociotorresmancera_female leadership-startups-liderazgofemenino-activity-7056274875560116224-PR0J?utm_source=share&utm_medium=member_desktop	485
LinkedIn	https://www.linkedin.com/posts/rociotorresmancera_sustainable-female-leadership-in-portugal-activity-7061319516642754561-vQsk?utm_source=share&utm_medium=member_desktop	102
LinkedIn	https://www.linkedin.com/posts/rociotorresmancera_consumer-awareness-for-responsibility-to-activity-7071847727822774272-Zpwu?utm_source=share&utm_medium=member_desktop	115
LinkedIn	https://www.linkedin.com/posts/rociotorresmancera_ebencongress-sustainableleadership-millennials-activity-7073990553364832256-NG5R?utm_source=share&utm_medium=member_desktop	200
LinkedIn	https://www.linkedin.com/posts/rociotorresmancera_questionnaire-on-responsible-consumption-activity-7074407575022149633-5jcP?utm_source=share&utm_medium=member_desktop	135
LinkedIn	https://www.linkedin.com/posts/rociotorresmancera_cuestionario-sobre-consumo-responsable-activity-7076538751014846464-gs0b?utm_source=share&utm_medium=member_desktop	55
LinkedIn	https://www.linkedin.com/posts/rociotorresmancera_questionnaire-on-responsible-consumption-activity-7076540388877942784-HBic?utm_source=share&utm_medium=member_desktop	36
Facebook	https://www.facebook.com/rsctalent/posts/pfbid02hSMAUT1xQvMVd5y7TkEQND4K9JE2iVd9QyaTmpozm1dtK6seLDh717YNFFZgCv3gl	14
Facebook	https://www.facebook.com/rsctalent/posts/pfbid02iHPBvDFfQqg1wxj476WuvJQMm6jaHDZpjXKYe4pEfRM1vWq6GA7bh1ePVawRgk6Bl	10

(*continued*)

Table 6. (*continued*)

Action type	LINK	People reached
Facebook	https://www.facebook.com/rsctalent/posts/pfbid02xcugbKog1zAFDXCWgtbcmLSDmQKPpWH1BJUrD9EYa8ygvnjSwZt6WcSMbbRJMneHl	2

Table 7. Communication (Partner 7)

Emails	Date	Nº items	Video calls	Other communications	People contacted
Received	1st sem	119	Coordination	Meeting	Partner
Sent	1st sem	56	KoM	Meeting	Partner
Received	2nd sem	100	Group EFE	Canal Sur	Media
Sent	2nd sem	115	Follow up	Coordinator	Other

Table 8. Test & validation (Several partners)

Action	Country	Area	Target	Participants
Face-to-Face	Germany	General / Resources	HEI Youngs	25
Hybrid	Spain	General	Adults	23
Face-to-Face	Portugal	Clothing / Resources Mobility / Food	Adults	31
Hybrid	Italy	General / Clothing Food	Adults	122
Face-to-face	Belgium	Mobility	Adults	11

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Science Communication Within Erasmus+ Projects: The FairFood Project

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Abstract. The concept of Science Communication is broad and plays an important role in society. Higher Education Institutions have always been privileged places to disseminate scientific knowledge and impact the way citizens value, apprehend, and use that knowledge. Public engagement generated by trust in scientists is one of the paramount goals of Science Communication, with implications at societal level, whether utilitarian, economic, cultural, or institutional. The concept of Education 5.0 creates a totally new array of opportunities and challenges. In a digital society, filled with different communication channels and actors, the proper dissemination of research results constitutes a relevant aspect of Science Communication. Erasmus+ projects are an important source of knowledge since one of their aims is to generate practical and tangible outputs with societal impact. This paper addresses the Dissemination Plan of an Erasmus+ project, FairFood for a Smart Life, dedicated to the preservation of the Mediterranean Diet, by detailing the activities implemented over two years. The diversity of online and offline approaches was designed to foster a change in behavior based on Science Communication, congregating training, research, and monitoring. The FairFood project constitutes an example of how education can galvanize change and how Science Communication can raise awareness in society at large by performing an instrumental role in knowledge dissemination.

Keywords: Science Communication · ERASMUS+ · Projects · Dissemination Plan · Education

1 Introduction

1.1 Science Communication in Education in the Digital Era

Science Communication (SC) in Education aims to disseminate scientific knowledge to the public through the communication of research results. In this field, Higher Education Institutions (HEIs), as privileged places at the forefront of scientific production, have the additional mission of actively contributing to this dissemination. The concept of SC is broad, including how citizens use the scientific knowledge produced in academia,

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leading to public engagement with science through specific channels and activities, namely by the establishment of partnerships among HEIs. In the digital era, the concept of Education 5.0 rises as an unavoidable pillar to be shared among HEIs, students and society, accompanying a profound transformation in the way we perceive education, training, research, and particularly its dissemination.

According to [1], HEIs have fundamental roles to play as a source of expertise, as trainers in many areas, as researchers and namely as monitoring entities of scientific research ethics. One of the questions that arises is "How do science communication scholars talk about science communication's role in wider society?" [2] (p.120). In the founding text of [3], the authors ask why should we care about the public understanding of science, giving some clues on cultural values or role in democracy, but not much further. Later papers on the topic worry more about skills and content production rather than on the effects of communication (e.g., [4]). However, these reflections include teaching goals on societal implications, processes, concepts and institutions, together with the role of participants. Hence, the implications in society become pivotal, and using science to help make better decisions is one important aspect. Another facet is ethics of science communication, with the paper of [5] being quoted when distinguishing strategic and democratic communication (either to democracy or to more individual/corporate goals). In this respect, how we learn and what we learn demands new approaches from educators and researchers. The co-creation of content alone is an overwhelming transformative variable when communicating science [6]. Thus, authors [7] question how to use communication to impact the world positively, and science communication contributes to this aim, considering knowledge a resource that must be used properly. These are issues on the societal role of SC, but there are also utilitarian and economic arguments, together with cultural and democratic ones.

Trying to explicit the role of SC in the contemporary world and how it can be catalogued, the study of [2] outlined five themes: a) Accountability (duty or responsibility for those funded by public resources, and mandatory if they want to obtain trust; establishment of a direct link between public funding and public communication); b) Pragmatic roles (or instrumental roles; useful to particular layers of society by providing knowledge of practical value); c) Enhancing democracy (mediating role, acting as input for debate in public spheres; has also a normative role in societal models); d) Culture (overlaps with the democratic role; science is portrayed as an achievement of modern societies with educational potential); e) Promotional purposes (this role has been growing and it is viewed as a problem as HEIs consider many times SC in terms of reputation, ignoring the reflexive dimensions of good-quality research).

Also, [8] explored trust as a main variable in perception of scientific work when communicating science to the public. Scientists are expected to contribute to public engagement, but communication is often directed solely to increase comprehension and augment credibility. However, knowledge on a topic does not have a direct relation to the change of attitudes that benefits science and public perception of scientists. Generally, public perceptions of scientists are positive, not only in stream media but also in social media. Still, scientists must behave according to perceptions and foster trust-related beliefs. It is a fact that education and science are powerful tools that can effectively lead to profound changes in society. In a digital era and in the knowledge society, science is

a trigger and a driver for change in all aspects (e.g., economy, social welfare, decision making). The interaction between science and society has suffered profound changes, and this is a moment of crisis for SC, since the content is deployed by a series of actors (e.g., [9]). New communicators have appeared (e.g., influencers, activists, corporate communicators) in a fragmented public sphere, which presents opportunities but also challenges. Also, SC needs to reflect on relationships between science, society and media. In fact, according to the study of [9], trainers tend to see scientists as seeking individual or external goals, and not communication-oriented goals. Research also has found inconsistency between positive associations of training experiences of scientists and their intentions to communicate. For those authors, outputs focus more on the impact they perceive rather than on whether audiences perceive improved communication skills as a result of training. Readjustments have been taking place, with the cultural shift being one of the hardest to achieve.

In sum, the societal impact is a very important aspect in science. In Education 5.0, the gathering of efforts at national and international levels in the pursuit of common strategies among HEIs and other relevant actors is even more crucial [10]. Research is not assessed solely based on scientific relevance, but also increasingly on the value it generates for society. This reflects a change in paradigm, in the relation between science and society, in which the former should provide scientifically robust knowledge, useful for society, in a close partnership with societal stakeholders [11].

1.2 ERASMUS+ Projects and Science Communication

This work focuses on the case of an ERASMUS+ project included in Key Action 2: Cooperation for Innovation and the Exchange of Good Practices, more specifically KA202 - Strategic Partnerships for Vocational Education and Training. These projects aim to disseminate their results at national and international levels, and their tangible outputs shall add value to the community, may it be at local, regional, national, or European levels. This kind of projects puts a strong emphasis on dissemination activities [12]. One of the key documents of these projects is the Dissemination Plan (DP), which aims to publicize the project results, thus ensuring that they are duly recognized and implemented on a large scale. To guarantee an effective dissemination and maximize the impact of the project results, the DP aims not only to raise awareness regarding the project contents, but also to provide information on their quality and relevance. The concept associated with the DP has two dimensions. In a horizontal dimension, it is important that the plan contains all activities capable of strengthening communication and dissemination between the project stakeholders. In a vertical dimension, it is important that all activities aimed at target audiences and end consumers are also considered [13].

The purpose of this work is to present the implementation of SC initiatives within an ERASMUS+ project and demonstrate the value of international cooperation tools to propel societal changes.

2 Materials and Methods

2.1 The FairFood Project

Even though a correct diet is a well-known source of health, there are many different reasons that can lead people to eat poorly. To overcome this problem, it is essential that we return to a traditional and healthy diet, habits that run the risk of being lost due to changes promoted by globalization. The ERASMUS+ project FairFood for a Smart Life, aims to contribute to nutritional education inspired by the Mediterranean Diet (a UNESCO intangible cultural heritage). The project, implemented from 11/01/2020 to 10/31/2022, was coordinated by the University of Malaga, and brought together six partners from four European countries. An Open Educational Resources (OER) platform was created and designed to accommodate the project [6].

2.2 The FairFood Dissemination Plan

The DP designed for FairFood used different approaches, methods, and instruments, according to the nature of each partner's profile. Among them, we highlight face-to-face, media-based, and performance activities. Face-to-face activities included workshops, seminars, and presentations. As media-base activities, the DP distinguishes between internet-based (e.g., e-newsletters, networks), paper-based (e.g., flyers, articles) and TV/radio-based activities (e.g., interviews, presentations). The performance activities were developed as the project work packages were implemented. (e.g., pilot courses, evaluation activities). The DP was put into practice since the very beginning of the project and still continues to be implemented, taking into account all the particularities of the target group and adjustments to the project different stages [13].

To conduct the design of the DP strategies, seven guiding questions were formulated: 1. Why disseminate; 2. What to disseminate; 3. Who to disseminate to; 4. Who will do it; 5. When will it be done; 6. How will it be done; and 7. How will it be evaluated. To increase the impact of the DP, the partners identified relevant stakeholders, such as professional associations (e.g., Association of Professional Cooks of Portugal, Portuguese Nutrition Association), social organizations (e.g., Club Gastronómico Kilómetro Cero), cultural foundations (e.g., Fundación Española de la Nutrición), schools (e.g., Malaga School of Hospitality - La Cónsula), and others (e.g., Buonissi-mo.it). The DP for SC was designed to give visibility to the main results of the project, both during its life and in the 2 years after its completion [13]. To record all the activities, a dedicated dissemination reporting tool was created. This document was regularly completed and updated by partners, with each of them having the possibility to customize it according to the tools used to maximize the dissemination of project results. The document included different offline and online categories [13].

The DP for FairFood also included the dissemination initiatives involving different stakeholders, like policymakers, authorities and other relevant individuals who can determine educational programs or have influence on setting educational curricula. To record all the activities regarding this point, another document was created to help partners regulate their DP at this level. The document encompassed different ranges of dissemination like European, local or national. Finally, a virtual platform in open access was

implemented for the FairFood project, where all the resources were available in five languages.

3 Results

This section exhibits the results achieved with the implementation of SC initiatives within the FairFood project. The outcomes provide a concise and accurate description of the initiatives, the different forms they took, and the number of people reached. Given that dissemination is considered closely related to the exploitation of project results in terms of integration and multiplication of achieved results, a well-structured DP is an essential instrument to maximize the value of project outputs and allow their active and concrete use at local, regional, national, and European levels.

3.1 Offline and Online Dissemination

The following tables display some of the results achieved both in the offline (Table 1) and the online (Table 2; Appendix I) tools.

Table 1. Offline SC initiatives and results

Action Type	Country	Level	Target	People Reached
Dedicated events Press releases Courses Brochures TV report	Spain	International European National Regional Local	General population Stakeholders Professionals Students	75524
Dedicated events Press releases Publications	Portugal	International European National Regional	General population Stakeholders Students Teachers/trainers	16491
Dedicated events Courses	Italy	National Regional	General population Students	65
Dedicated events	Belgium	International	Professionals Students Teachers/trainers	75

The diversity of initiatives illustrates the impact the DP can have on the target audiences (practitioners, teachers, general public, institutional stakeholders), directing the content of SC to specific layers of the population, thus adapting the discourse according to the scientific literacy of the public and resonating with the societal impact referred in the literature, namely in [7] or [2], when specifying the accountability and pragmatism of SC. Since the topic of the project was the Mediterranean Diet, the cultural impact was also relevant, actively spread among diverse media channels and with face-to-face encounters involving schools and institutions.

Table 2. Information on SC initiatives

Action Type	People Reached
Own website	10481
Press Release	185735
Blog	19250
Social Network posting	1943
Online TV participation	50912
YouTube	95
Dissemination event	500
Web Radio Speech	4200
Social Media Campaign	7240

The consistency of the FairFood DP contributed to build feelings of trust and credibility regarding the outputs of the project, in an attempt to foster a change in behavior based on science communication, as observed by [8].

3.2 Science Communication Initiatives and Stakeholders

Stakeholders are fundamental to an ERASMUS+ project, with FairFood being no exception. Table 3 presents data regarding this involvement.

Table 3. Stakeholders achieved by SC initiatives

Stakeholders	Level	People Reached
Policy makers	European / National / Regional	67
Deputies	National	741
European Parliament	European	153
Councilors	Local	77
Other stakeholders	International	20

As stated by [11], the close involvement of stakeholders in the DP allows the diffusion of scientific knowledge and makes it useful in society. The FairFood DP accomplished the dissemination goals of the project by including regional, national and international stakeholders, contributing to the democratic principle illustrated by [2] when acting as a mediator in the promotion of debate on public health issues.

3.3 Science Communication Through the OER Platform

The interaction with the project was also monitored through systematic registers of those who accessed the OER platform to have access to all the FairFood results. The embedment of the project results into the OER platform reveals its fundamental importance in the dissemination and exploitation of project results, as shown in the figures in Table 4.

Table 4. OER and SC

Month	Daily Average						Monthly Totals			
	Hits	Files	Pages	Visits	Sites	Kbytes	Visits	Pages	Files	Hits
average'22	9107	6099	932	249	2445	5182451	7343	27595	182950	273386
dec/22	5771	4264	876	346	3490	3615090	7621	19276	93813	126979
nov/22	9195	6138	839	336	2948	5734639	10107	25179	184143	275860
oct/22	22213	15380	1138	355	**3797**	14900870	**11011**	35278	476801	688609
sept/22	5150	4148	1093	275	2483	5679585	8260	32793	124443	154526
aug/22	3125	2783	768	273	2128	5066298	8481	23814	86291	96877
jul/22	4249	3455	659	267	2397	5935071	8296	20438	107130	131719
jun/22	14747	9687	850	251	2732	7899330	7559	25503	290615	442417
mai/22	12830	8529	816	246	2686	6906527	7634	25310	264410	397731
apr/22	9783	6421	976	232	2130	3181311	6977	29282	192639	293490
mar/22	10579	6262	674	150	1638	1443461	4670	20894	194139	327955
feb/22	5468	2977	1357	131	1485	843335	3672	38020	83383	153128
jan /22	6172	3148	1140	123	1421	983893	3828	35354	97595	191346
average'21	1448	1172	194	77	1259	1440179	2345	5881	35539	43837
dec/21	2382	1850	248	120	1705	1496269	3725	7706	57377	73850
nov/21	3698	2515	343	108	1819	2823167	3256	10306	75470	110966
oct/21	1567	1273	249	93	1763	1374838	2811	7474	38198	47031
sept/21	1071	912	245	100	1668	1416040	3005	7351	27376	32157
aug /21	794	677	202	95	1114	1373641	2973	6274	21003	24616
jul/21	937	857	183	102	1424	1973388	3168	5682	26587	29052
jun/21	1974	1782	299	103	1653	2675762	3092	8970	53479	59241
mai/21	1143	1014	157	53	1054	1684446	1663	4895	31456	35438
apr /21	976	898	133	58	1058	740818	1758	3998	26963	29304
mar/21	1565	1446	150	59	1184	1245561	1858	4654	44827	48537
feb/21	1157	742	97	20	453	378357	581	2716	20800	32398
jan /21	111	94	17	8	212	99863	250	547	2937	3448
average'20				**162,666667**						
dec /20	16	10	3	2	99	4947	85	102	312	502
nov/20	38	25	9	8	73	3560	57	64	179	270
Totals						**YEAR 2022**	**88116**	**407595**	**2657414**	**3850512**
						YEAR 2021	**28140**			
						TOTAL	**116398**			

The adaptation of content materials to the new digital paradigm was fruitful, namely in the design and implementation of 50 micro-courses on the Mediterranean Diet in five languages and in two levels of difficulty, with the possibility of being easily adopted by lecturers at secondary schools and vocational schools of tourism, hospitality, and cooking. The fact that students participated actively in the project by recording videos and preparing communication plans enhanced the outcomes of the DP.

In addition, the significant increase of visits to the OER platform indicates the success of the SC dissemination initiatives through this tool, offering the possibility to navigate through the several outputs and/or direct the search to specific topics, according to user needs. Once again, the consistency of the DP contributed to build trust and confidence in scientific knowledge conveyance, while raising awareness to the importance of preserving and encouraging the use of the Mediterranean Diet by the population. As observed by [9], the FairFood DP worked as a trigger to stimulate the curiosity and interaction of the public, making use of new digital actors such as influencers, bloggers and well-known chefs, to municipal entities, European representatives, TV channels, podcasts, online contests, projects elaborated by students, sponsoring of companies and other social entities. The online initiatives inside and outside the academia listed in Table 2, illustrate the continuous effort in sustaining the project's goals with impact on society.

4 Discussion

The change of paradigm in education is a fact. New and unpredictable opportunities and challenges are now part HEIs goals and commitments. Hence, the success of science depends a great deal on the success of communication. The FairFood project is an example of good practices in terms of SC in education for several reasons. It disseminates scientific knowledge resulting from two years of preparation of 50 online courses on a topic with a vast research portfolio, with teams of experts from four different countries in pivotal areas, including two HEI. The Mediterranean Diet is a UNESCO intangible heritage, therefore of interest to the general public all over the world. The fact that the OER platform offers the content freely in five languages contributes in a relevant way to attract target audiences, together with the practicality of content adoption by educational institutions and accessibility of common citizens who, in addition, can be further engaged by the acquisition of a certificate when completing the modules. The array of approaches, both online and offline, along with the official implementation period of the project and beyond, is aligned with the [1] observation, as it congregates training, research and monitoring. A special output underlying the DP, was the opportunity to congregate different social actors in each country to work as associated partners for two years, resulting in a more committed and credible institutional communication on their side, in close connection with academia and science, and clearly acting as mediators in public discussion of such important issues. In addition, the fact that some of them were schools, contributed to augment the success rate of the DP. To talk about SC is, therefore, a task that should focus on the role of science in helping people making better decisions. A goal that we believe has been achieved by FairFood as it makes use of digital means to transmit knowledge in a simple, direct, and appealing way, impacting the target audiences positively, as pointed out by [7]. The DP of FairFood, namely the offline activities,

allowed for all partners involved to raise awareness in their communities, performing an instrumental role by providing practical knowledge, fostering public discussion, preserving cultural values, and gain notoriety at institutional level [2]. The online DP was fundamental for the project to be present in social networks, a privileged and unavoidable way to reach potential audiences and allow for the crossing of knowledge from different scientific sources. Hopefully, the outputs of FairFood will contribute to a change in habits regarding food and nutrition, and, in that case, confirming the perception of the general public of scientists and researchers as important and trustworthy social actors. The role of digital transformation in the dissemination of traditional knowledge was, therefore, one of the main outputs of this project, confirming that science has the power to bring generations together for a common purpose.

5 Limitations

The main limitation of the project was the fact that not all countries of the Mediterranean Basin were included in the consortium. The projection would necessarily be higher, leading to a more impactful knowledge dissemination and trustful role of science communication. Future and broader research in this topic would thus be encouraged, namely by further Erasmus+ initiatives, not only to continue preserving ancestral knowledge through digital means, but also to foster sustainable and healthy habits globally through international cooperation.

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Appendix

Detailed Information on SC Online Initiatives.

Action Type	Link	People Reached
Own website	https://www.ihfeurope.eu/2020/12/09/fair-food-for-a-smart-life-ihf-asbl-joined-the-online-kick-off-meeting-of-fairfood/	10423
Press Release	https://www.diariosur.es/cronica-universitaria/universidad-malaga-lidera-20210406000307-ntvo.html	6400
Own website	https://www.fairfoodproject.eu/read_news_es.php?id=18	58
Blog	https://blogsaverroes.juntadeandalucia.es/erasmuslarosaleda/fair-food/	3350
Blog	https://www.uma.es/smart-campus/info/127638/consumo-responsable-productos-locales-y-de-temporada/	2500

(*continued*)

(*continued*)

Action Type	Link	People Reached
Social Network posting	https://www.facebook.com/iwsmalaga/posts/6050330894991953	305
Social Network posting	https://www.facebook.com/fairfoodproject/photos/a.155842186359846/282141700396560/	203
Blog	https://blogsaverroes.juntadeandalucia.es/erasmuslarosaleda/2021/10/17/avanzando-en-el-food-toolkit/	3350
Social Network posting	https://www.facebook.com/iwsmalaga/posts/6861380413886993	305
Press Release	http://es.globedia.com/fairfood-smart-life-balance-lecciones-aprendidas-ano-implementacion	6881
Press Release	https://www.notas-d-prensa-gratis.com/nota/31562/fairfood-for-a-smart-life%3A-balance-de-las-lec.html	1028
Online TV participation	https://www.canalcentral.pt/?a=vr&v=1054	912
Youtube	https://verakis.com/dieta-mediterranea-muito-mais-do-que-alimentos/	95
Blog	https://blogsaverroes.juntadeandalucia.es/erasmuslarosaleda/2022/03/26/fgu-se-une-a-fairfood/	3350
Press Release	https://www.prlog.org/12912827-aprende-comer-mejor-con-la-comida-tradicional.html	297
Social Network posting	https://www.instagram.com/p/CcNlzLmo5xK/?igshid=YmMyMTA2M2Y =	825
Press Release	https://idpeuropa.com/imparare-a-mangiare-meglio-con-il-cibo-tradizionale/	14349
Social Network posting	https://www.facebook.com/iwsmalaga/posts/7519625604729134	305
Press Release	El proyecto FairFood busca promover una alimentación saludable entre los jóvenes europeos (europapress.es)	49500
Press Release	https://www.diariosur.es/cronica-universitaria/proyecto-fomenta-consumo-20220517000141-ntvo.html	6400
Blog	https://blogsaverroes.juntadeandalucia.es/erasmuslarosaleda/2022/06/04/fairfood-en-la-egw/	3350
Press Release	Un proyecto Erasmus busca promover una alimentación saludable entre los jóvenes europeos (pmfarma.es)	325

(*continued*)

(*continued*)

Action Type	Link	People Reached
Dissemination event	https://www.youtube.com/watch?v=QdKypsVPYo4	500
Web Radio Speech	https://www.uma.es/relaciones-internacionales/noticias/el-proyecto-fairfood-smart-life-eleva-su-impacto-internacional/	4000
Press Release	https://www.internetwebsolutions.es/iws-fairfood-meeting-tercero/id/48	180
Social Media Campaign	https://www.instagram.com/p/Ce6btx3oMBx/?utm_source=ig_web_copy_link	817
Press Release	https://verakis.com/fairfood-talks-uma-visao-multissetorial-da-dieta-mediterranica-em-portugal/	500
Social Media Campaign	https://www.facebook.com/100057215329756/posts/520776606506179/?d=n	1423
Blog	https://blogsaverroes.juntadeandalucia.es/erasmuslarosaleda/2022/10/04/fair-food-publica-materiales/	3350
Social Media Campaign	https://fb.watch/gnQ1OQN8-L/	309
Web Radio Speech	http://envision.web.ua.pt	200
Press Release	https://www.internetwebsolutions.es/iws-test%20de%20autoevaluaci%C3%B3n%20de%20fairfood/id/188	40123
Press Release	https://idpeuropa.com/index.php/2022/10/28/closing-meeting-of-the-erasmus-fairfood-project-in-brussels/	30797
Social Media Campaign	https://www.ua.pt/pt/noticias/13/78412	5000
Online TV participation	https://www.canalsur.es/Tesis-5255.html	50000

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The Impact of Gender on Financial Decision-Making: A Case Study

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Abstract. This study investigates the impact of gender on financial decision-making, focusing on gender inequalities in top management positions within a Portuguese banking institution. Through a case study, we analyze employment data, academic qualifications, and maternity-related absences to assess female representation in leadership roles. Drawing on a comprehensive literature review, the research highlights persistent gender disparities in employment, particularly in senior executive positions, despite women's high academic qualifications. The analysis reveals that women are significantly underrepresented in decision-making roles, with only 19% of senior executives and 4% of board presidents being female, reflecting barriers such as the glass ceiling and maternity-related challenges. These findings align with broader trends in the European Union and Portugal, where gender employment gaps and part-time work disparities persist. The study underscores the need for inclusive strategies aligned with the Society 5.0 paradigm to enhance female participation in financial leadership, offering insights into the benefits and challenges of greater gender diversity. By deconstructing assumptions about gender and leadership, this research contributes to the discourse on equality and inclusion in the banking sector.

Keywords: Gender · Top Management · Financial Decision-making · Portugal · Society 5.0

1 Introduction

The Society 5.0 paradigm envisions a variety of differences where the well-being of all and an inclusive perspective become increasingly imperative strategies. In this context, gender-related issues have received special attention due to growing awareness of equality and social inclusion. Despite progress, such inequalities continue to hinder women's advancement, impeding both economic and social growth [1]. This study aims to analyze the benefits and potential drawbacks of a stronger female presence in leadership roles involving decision-making, thereby deconstructing some assumptions and preconceived notions on the topic. To this end, we conducted a case study using publicly available data from a banking institution.

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This paper is organized into four sections. The first is introductory. The second provides the theoretical framework. The third is dedicated to the case study, guided by themes from the literature review. The fourth presents final reflections.

2 Literature Review

2.1 Employment

According to the literature, even for non-executive roles, there is a significant disparity in employment between men and women. Using statistics from the European Union's statistical office (Eurostat), it is evident that the gender employment gap, while decreasing over recent decades, remains noticeable across EU countries. Between 2009 and 2014, the gap narrowed from 13.4 percentage points to 11.1. However, from 2014 to 2021, despite continued reduction, the change was less significant, dropping from 11.1 to 10.8, resulting in 46.3% of employed individuals being women in 2021 [2].

In Portugal, over the same period, the gender employment gap decreased from 10.8% in 2009 to 6.6% in 2014 and 5.9% in 2021 [2]. Data from 2022 indicate employment rates of 80% for men and 69.4% for women [3]. These figures show that, despite increased discussion on gender inequality, actual changes in employment numbers have been less pronounced.

Other factors highlight the extent of these disparities. According to the 2022 Report on Equality Between Women and Men in the EU by the European Commission, part-time employment among women remains significant. In 2020, the year the pandemic began, 29.1% of employed women worked part-time, compared to 7.8% of men [4]. Among the causes of this divergence, maternity and unpaid workload are addressed later in this review. As noted by [5], the COVID-19 pandemic exacerbated this issue, with many women facing increased unpaid work (e.g., family and household responsibilities), leading one in four women to consider leaving work or shifting to lower-responsibility roles. Furthermore, [5] notes that, despite women comprising about half the workforce, they are significantly underrepresented in leadership roles. Similarly, [6] states that women in the EU remain clearly underrepresented in the labor market, particularly in top management positions. Among G20 countries in 2017, women accounted for, on average, 17% of board members and 12% of executive committee members in the top 50 listed companies. According to a Eurostat study [7], only 37% of managers in the EU were women, with 28% of board members and 18% of senior executives in listed companies being women.

In Portugal, Eurostat data show a slightly above-average female presence in managerial roles (40%) compared to the EU. However, for senior executive positions, Portugal falls below the EU average, with only 15% female representation. A study by [8] on 45 Iberian companies reached similar conclusions, noting high gender representation in Portugal's workforce but limited presence in leadership roles, such as Chief Executive Officer (CEO) and N-1 positions (one level below CEO). In their sample, 9% of CEOs and 30% of N-1 positions were held by women. For N-2 and N-3 roles, percentages align with global trends at 32% and 34%, respectively. The study concludes that the gender gap in Iberian leadership roles (N-3 to CEO) is at least 30%, largely due to the glass ceiling, defined as invisible barriers preventing women's career advancement [8]. Similarly, [9]

describes the glass ceiling as a transparent barrier that women with requisite skills can see but struggle to break through to reach top corporate hierarchies.

2.2 Education and Academic Level

Another commonly cited reason for labor market inequalities is intellectual capacity linked to academic qualifications. This hypothesis is supported by [10], which suggests that the scarcity of women on corporate boards may be due to a lack of academically qualified women for such roles.

The United Nations Children's Fund (UNICEF) states that investing in girls' education transforms communities, countries, and the world [11]. It argues that education enables women to lead independent, successful lives and participate in decisions affecting them. In Europe, according to [12], in 2020, of the 18 million tertiary education students (including specialized vocational courses, bachelor's, master's, and doctoral programs), 54% were women. This suggests that, based solely on the number of academically qualified individuals, women should have an advantage. Breaking down the data by academic level, only doctoral programs show slightly fewer women than men (53.4%, 57.2%, and 48.7% for bachelor's, master's, and doctoral degrees, respectively) [12]. In Portugal, of the 2.1% of these students who were Portuguese, 53.8% were women, indicating a slight female majority in tertiary education, close to gender parity [12]. Of these 18 million tertiary education students, 2.1% were Portuguese, and of those, 53.8% were women, indicating that, in Portugal as well, there is a slight female majority in tertiary education, with figures close to gender parity [12]. Women in Portugal have higher representation in all tertiary cycles except for qualified vocational courses, where men predominate.

Regarding fields of study, in 2020, women in the EU were the majority in education, health and welfare, arts, humanities, social sciences, and journalism. Conversely, engineering, manufacturing, construction, and information and communication technologies had a clear male majority [12]. The fields of business, administration, and law, which include finance, were the most popular, with 21.8% of students. Women comprised 54.6% of these students [12]. However, [13] notes that in prestigious Master of Business Administration (MBA) programs, which prepare students for business, management, finance, and consulting, female participation remains disproportionate. In their sample from an elite international school (unnamed), only 23% of students were women. Thus, while female presence in MBAs is low, EU data demonstrate women's high academic qualifications. Contrary to [10], the lack of academically qualified women does not justify their underrepresentation in leadership roles.

2.3 Maternity

Maternity and its associated burdens, where women typically assume the primary caregiver role, is another factor cited for women's difficulties in career progression and accessing senior roles. Women face challenges managing this role, entering, and remaining in the labor market, as maternity significantly impacts their professional lives, regardless of potential earnings [14]. This is often because mothers work part-time or leave the workforce to focus on motherhood. It is also common for women to take maternity leave, even when both parents are eligible, due to social norms and economic factors,

as it often makes sense for the lower-earning parent—frequently the woman—to stop working [15].

A study by [16] in China, interviewing 20 recruiters to assess gender discrimination in hiring, found that none considered pregnancy or childbirth when hiring recent female graduates, as they were less likely to intend motherhood at that age. However, 17 of 20 recruiters noted that for experienced workers (older), maternity was a factor in hiring decisions.

In the Netherlands, a study by [17] evaluated employer perceptions of candidates for a female-dominated job (primary school teacher) and a male-dominated job (software engineer). A small percentage of employers expected mothers to be less dedicated, and a larger percentage anticipated mothers would work minimal hours. However, these expectations did not significantly affect hiring intentions, suggesting no clear discrimination.

Maternity impacts not only labor market entry and retention but also earnings. According to [18], children reduce women's labor market earnings, particularly for children under six, due to increased caregiving time. Regarding unpaid work related to maternity, [14] notes that after the first child, women's weekend domestic work (e.g., cooking, cleaning, laundry) increases by 280–300%, compared to 170–200% for men, depending on whether they are the primary breadwinner.

The COVID-19 pandemic highlighted unpaid work disparities. As remote work became mandatory, tasks typically women's responsibilities, such as supervising children's schoolwork, became more challenging, often overlapping with professional duties [19].

For female managers, the scenario is similar. A study by [20] on work-family balance post-maternity leave found that women show greater affective commitment and engagement when there is open communication, psychological support, and flexible time management. Similarly, [21], studying female engineering managers in Sweden, found that participants felt protected from retaliation post-maternity leave, with some promoted during leave. However, they described challenges managing senior roles with family life due to travel and long hours, mitigated by support from spouses and supervisors. Lack of such support led some to leave previous organizations.

Thus, regardless of profession or role, mothers require enhanced personal and professional support to balance both spheres without harming their careers and ambitions.

3 Case Study

This case study aims to link the literature review with human resources data from a Portuguese banking institution, examining indicators such as employment, education and academic level, and maternity. The study is organized by the main themes of the literature review, in the same order: employment, hierarchical position (as a proxy for salary), education and academic level, and hours absent due to maternity/paternity (as a proxy for maternity's impact).

The case study focuses on a cooperative financial group specializing in retail banking, offering products and services including daily banking solutions, digital platforms,

financing for individuals and businesses, and savings or investment products (e.g., deposits, investment funds, insurance).

The study is based on the institution's 2021 social balance sheet, 2022 financial reports and accounts from 71 associated entities, and information from each entity's website.

To understand the institution's current trend regarding female presence in decision-making roles, we used the 2021 social balance sheet for broader HR statistics and 2022 reports and accounts for detailed data on the composition of governing bodies.

3.1 Employment

The institution's functional distribution is characterized by the following categories: Senior Executives, Mid-Level Executives, Intermediate Executives, Highly Qualified/Qualified Professionals, Semi-Qualified Professionals, and Non-Qualified Professionals. By analyzing the latest social balance sheet provided by the institution, we can examine the employment statistics presented in Table 1. Regarding permanent employees, it is noted that, of the 3671 employees at the institution, 1913 (52%) are men and 1758 (48%) are women.

Table 1. Functional distribution of the institution (2021)

Functional Distribution	Gender	Employees	Total
Senior Executives	M F	152 35	187
Mid-level Executives	M F	51 36	87
Intermediate Executives	M F	463 178	641
Highly Qualified Professionals / Qualified Professionals	M F	1229 1407	2636
Semi-qualified Professionals	M F	8 10	18
Non-qualified Professionals	M F	10 92	102
Total			3671

Considering this percentage alone, it can be concluded that, in general terms and without applying the functional breakdown, the ratio of men to women employed at the institution is relatively close to balance. However, to conduct a more detailed analysis of these percentages, we proceed to examine these figures through the lens of the institution's functional distribution, as outlined in its social balance sheet. Based on the information contained in the final section of the social balance sheet, where each

role is assigned to its corresponding function, including the aforementioned functional distribution, it is possible to understand the institution's classification criteria.

In our study, we defined employees in decision-making positions as those in Senior and Intermediate Executive roles, as we consider these to be the positions with the greatest influence. Accordingly, the statistics presented below use the figures for Senior and Intermediate Executives as a benchmark, representing the sample we aim to analyze. By combining the values from Table 1 and the functional segregation mentioned above, it is evident that women outnumber men only in the three lowest hierarchical levels, with the most notable disproportion in the Non-Qualified Professionals group, where 90% are women (92 out of 102 professionals).

According to the available information, Non-Qualified Professionals include roles such as supervisor, clerk, driver, attendant, cleaning assistant, and general services assistant. The significant presence of women in these roles aligns with findings previously reported by the European Parliament [22], which states that 24% of the gender pay gap is explained by the pronounced presence of women in low-paying positions. The perpetuation of these trends naturally hinders breaking the glass ceiling effect and normalizing female inclusion in top roles.

Conversely, the institution's Senior, Mid-Level, and Intermediate Executive roles exhibit a clear and predominant male majority. Analyzing the percentages based on our chosen benchmark, we observe that the greatest gender disparities occur in senior and intermediate roles, with 72% of Intermediate Executives being men (463 out of 641).

The disparity is even more pronounced in top positions, included in Senior Executives, where only 19% are women (35 out of 187). These figures are corroborated by data from the 2022 reports and accounts of each of the 71 entities under study. As shown in Table 2, the percentage of female presence in each governing body, regardless of role, is consistently below 50%, the threshold for gender parity.

Our analysis emphasizes the three main governing bodies prevalent in the institutions: General Assembly, Board of Directors, and Supervisory Board. Female representation is highest in the Supervisory Board (44%), followed by the Board of Directors (30%) and General Assembly (11%). For the most significant role, President of the Board of Directors, only 3 out of 71 presidents are women, representing 4% of the total.

This statistic most clearly demonstrates the lack of female representation at the top of the institution, which may be attributed to the factors discussed in the literature review. These data align with our earlier findings in the literature review regarding the limited presence of women in leadership roles and, consequently, the consistent predominance of men. Regarding salary differences, it is not possible to draw conclusions from the institution's social balance sheet, as the values provided are aggregated and pertain only to calendar years, without being broken down by functional distribution. To address this limitation, we assume hierarchical position as a proxy for salary levels.

3.2 Education and Academic Level

As noted in the literature review section, one argument used by [10] as a possible justification for the inequalities found in senior roles could be related to a lack of qualified women to fill leadership positions. However, the data from the institution reveal the opposite.

Table 2. Female presence in governing bodies (2021)

Governing Body	Role	Men	Women	Women per Body
General Assembly	President Vice-president Secretary	68 64 44	3 7 12	11%
Board of Directors	President Member Alternate	66 122 7	3 78 2	30%
Audit Committee	President Member Alternate	44 80 25	27 62 27	44%
Advisory Board	President Member	3 38	0 9	18%
High Council	President Member	4 28	0 3	9%
General and Supervisory Board	President Member	2 10	0 2	14%

Regarding academic qualifications (Table 3), it can be concluded that, with respect to higher education (bachelor's degrees, master's degrees, and doctorates), the number of women with higher academic qualifications exceeds that of men-54% of employees with higher education are women. These figures demonstrate that, in the case under study, the reason for the low number of women in leadership positions is unlikely to be related to their being less academically qualified.

Upon analyzing the data presented, we observe that the educational levels representing the vast majority of employees are secondary education and bachelor's degrees, accounting for 84% of all employees (1587 hold secondary education and 1505 hold bachelor's degrees, out of a total of 3671 employees). Secondary education comprises 62% men and 38% women, whereas the bachelor's degree level is substantially more balanced, with 46% men and 54% women.

It can also be noted that, despite the highly favorable statistics regarding higher education, when examining lower educational levels, we find that these too show a female majority. This statistic may be related to our earlier finding that there is a predominant female presence among the institution's non-qualified professionals, although this group of employees is not particularly significant in number.

3.3 Maternity

Regarding the issue of maternity and its demonstrated impact on women's career progression, based on the institution's data, the only metric we found to connect the findings from the literature review with the entity relates to the number of absence hours used by employees, justified by maternity/paternity reasons. It can be observed in Table 4 that, out of a total of 77607 h of absence from work, 85% of these hours were taken by

Table 3. Academic level of employees (2021)

Functional Distribution	Gender	Employees	Total
Pre-primary education	M F	0 2	2
Primary education	M F	0 43	43
Lower secondary education	M F	5 22	27
Upper secondary education	M F	88 74	162
Secondary education	M F	978 609	1587
Pre-Bologna bachelor's degree	M F	69 98	167
Bachelor's degree	M F	695 810	1505
Master's and Doctoral degrees	M F	78 100	178

women. This percentage suggests that it remains evident how women more frequently prioritize their family and caregiving roles over their professional lives.

Table 4. Absence hours (2021)

Absence Type	Gender	Hours
Maternity/Paternity	M F	11347 66260
Total		77607

Despite more equitable parental leave policies, the discrepancy remains clear. This analysis confirms that female representation in leadership roles is below parity and below the potential shown by the institution's data.

4 Final Reflections

Aligned with the Society 5.0 paradigm, gender equality in leadership and decision-making roles remains a relevant and persistent issue. This study explored the topic through a combination of existing literature and empirical analysis of a banking institution's data. It is evident that, despite progress toward inclusion and equality, women remain significantly underrepresented in such roles, particularly in the banking sector.

Key contributions include analyzing the benefits and potential drawbacks of increased female presence in leadership roles involving decision-making, thus deconstructing assumptions and preconceived notions on the topic.

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Accessibility of the Canvas and Blackboard Learning Management Systems: A Case Study at a Brazilian University

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Abstract. Between 2015 and 2019, there was a 27% increase in enrollment of students with disabilities in Brazilian undergraduate programs. Distance learning holds significant potential for attracting a large number of students with disabilities to undergraduate courses. However, educational institutions must ensure that their educational tools, such as Learning Management Systems (LMS), are of high quality and accessible before making them available to faculty and students. This paper presents the findings of accessibility assessments conducted on Canvas and Blackboard LMS's at a Brazilian University, aimed at supporting the engagement of students with disabilities. The methodology involved conducting interviews with students with disabilities to gauge their satisfaction levels, along with automatic inspections to identify accessibility violations. Two questionnaires, each consisting of 69 questions based on Web Content Accessibility Guidelines (WCAG) 2.1 guidelines, were administered to students for analysis. The results from the questionnaires and tool reports were organized and compared. The findings indicated that a subset of students with disabilities who used assistive tools expressed a preference for the Blackboard LMS. Additionally, it was observed that relying solely on automatic tools for analysis is insufficient for assessing the accessibility of LMS's. Furthermore, it was noted that certain WCAG criteria had a more pronounced impact depending on the student's disability. Overall, comparisons between the two LMS's revealed no significant differences in accessibility.

Keywords: Accessible learning platforms · Inclusive learning · Inclusive technologies · Instructional Systems · Distance Education · WCAG · LMS accessibility

1 Introduction

The 2030 Agenda for Sustainable Development, embraced by all United Nations Member States in 2015, aims to ensure peace and prosperity for people and the planet. Among its 17 Sustainable Development Goals (SDGs), Goal 4 focuses on ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all.

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Notably, the enrollment of students with disabilities (SwD) in Brazilian undergraduate programs increased by 27% between 2015 and 2019 [1]. Consequently, distance learning emerges as a means to engage a broader audience and integrate them into undergraduate educational settings. However, the preparation of these environments is essential [6]. Unfortunately, many universities worldwide lack accessibility in their learning systems and websites [14] [15].

Web Content Accessibility Guidelines (WCAG) and the IMS Global Learning Consortium provide guidelines, principles, and recommendations for creating and evaluating accessible content and systems to reduce accessibility barriers for people with disabilities [9, 17]. The WCAG Version 2, proposed by the W3C, provides layers of guidance, including principles, guidelines, success criteria, and advisory techniques. The principles support the foundation for web accessibility, followed by guidelines that outline the basic goals for making content more accessible to users with different disabilities. Testable success criteria are provided for each guideline, and there are advisory techniques for each of the guidelines and success criteria. The WCAG 2.1 provides 4 principles and 13 guidelines to make web content more accessible to users in general, and 17 out of 78 Success Criteria (SC) to address mobile accessibility and people with disabilities [18]. WCAG also establishes rules and compliance levels for evaluating software accessibility, including educational systems, and provides adaptable guidelines for different domains to help develop accessible content [2] and improve relationships among students, teachers, administrative councils, and staff of universities [8].

A Brazilian University, named Virtual University of the State of São Paulo (Univesp), caters numerous students and has proactively maintained robust and efficient digital platforms to support its teaching and learning processes. In 2021, the university transitioned from using the Canvas Learning Management System (LMS) to the Blackboard LMS. The Canvas platform, an open-source version hosted in the institution's cloud storage, incurred high costs and scalability concerns, along with technical service availability issues during educational activities. The Blackboard won a bidding process to serve its LMS options with high service-level agreements and data migration assurances. Canvas supplier opted not to participate.

The transition from one system to another, such as an LMS in an educational institution or any other management system within a company, may encounter resistance as it necessitates user adaptation to the new system. Adequate planning and post-implementation evaluation of system use are essential to ensure successful and qualitative migration. To assess system usability, standardization organizations and researchers have proposed methods to evaluate its effectiveness, efficiency, and user satisfaction within specific contexts of use [4, 10, 13, 16]. Additionally, accessibility is a critical qualitative aspect to consider, ensuring that products or services, such as software, are usable by all individuals, including those with disabilities. Accessibility laws exist to promote technology use by everyone, and incorporating accessibility guidelines into web designs is a beneficial practice to prevent accessibility violations. Designers should strive to address all accessibility violations to accommodate all potential users in their respective contexts of use. In educational settings, an accessible LMS can ensure equal educational opportunities for students with disabilities.

This study conducted an accessibility evaluation of the Canvas LMS and the Blackboard LMS used in the teaching-learning process of Univesp. The objective was to analyze and compare these systems to identify their accessibility benefits and drawbacks following the software migration from Canvas to Blackboard in the university. We aimed to measure the losses and gains from this exchange and accessibility was an essential aspect. To achieve our goal, questionnaires and automatic accessibility assessment tools based on WCAG 2.1 were employed. By gathering data from both SwD users and automatic evaluations, the study aimed to ascertain whether each LMS met the needs of the students and provide valuable insights into the accessibility.

2 Methodology

This study utilized the following approaches to assess the accessibility of Canvas and Blackboard: (1) conducting interviews with students with disabilities (SwD) using questionnaires that encompassed their assessments of the LMS's adherence to WCAG principles; (2) conducting inspections via automatic accessibility evaluation tools.

These methodologies, depicted in Fig. 1, are characterized by minimal cost and time requirements. WCAG principles were prioritized over guidelines or success criteria as they represent the highest level of guidance offered by WCAG 2.1.

2.1 Interviews with SwD

In support of our research endeavor, the university provided a roster of 307 students who self-identified as individuals with disabilities, when they enrolled at the university. SwD were enrolled in various undergraduate courses, including Pedagogy (81), Engineering (81), General Studies (73), Management (48), and Computer Science (24). We invited all of them via email to partake in our study by completing questionnaires, which encompassed inquiries regarding their socioeconomic background, experience with electronic devices, and familiarity with Canvas and Blackboard LMS. To ensure students encountered no difficulties in using the new LMS, we administered the Canvas questionnaire first. Prior to answering the questions, we informed participants that their participation was voluntary and they retained the option to decline collaboration at any point without facing consequences.

The questionnaire consisted of 69 questions organized into six sections. The initial section addressed socioeconomic aspects, while the subsequent section focused on device usage, internet accessibility, and assistive technologies. The remaining four sections concentrated on evaluating the accessibility of the LMS platforms in alignment with WCAG principles. SwD, using the LMS's, should analyze whether the LMS's content is:

- Perceivable: ensuring content and user interface components are presented in a manner perceivable to users.
- Operable: ensuring user interface components and navigation are operable.
- Understandable: ensuring information and the operation of the user interface are comprehensible.

- Robust: ensuring content is robust enough to be reliably interpreted by a wide array of user agents, including assistive technologies.

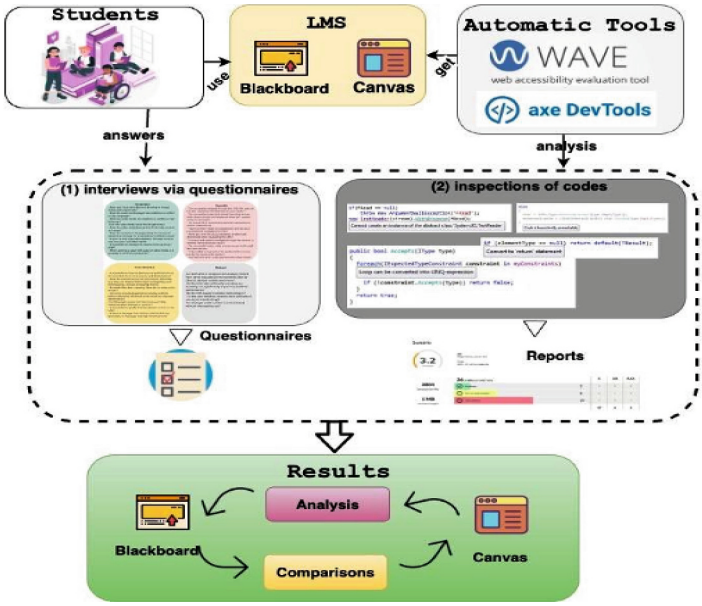

Fig. 1. Overview of accessibility assessment with users and automatic tools.

To delve deeper into the student demographic, we gathered data on various factors such as income, education level, employment opportunities, frequency of device usage, and technological proficiency.

The last four sets of questions were tailored to assess LMS accessibility from the perspective of students with disabilities, addressing each of the four WCAG 2.1 principles as depicted in Fig. 2. Each question provided a Likert scale for response options including "I strongly agree," "I agree," "I disagree," "I strongly disagree," and "Never needed this feature." The final version of the questionnaires was prepared using the Qualtrics® platform (XM Directory).

A scoring system was established to quantify and analyze questionnaire responses. For positively framed questions, a response of "I strongly agree" received a score of 5, while "I strongly disagree" was assigned a score of 0. Responses of "agree" and "disagree" were scored as 4 and 1, respectively. Blank responses or indications that a question did not apply ("Never needed this feature") were excluded from score calculations.The average score of the questions for each principle was used to calculate the score for that principle.

Participants were allotted 21 days to complete the questionnaires, with a 14-day interval between the analysis of Canvas and Blackboard LMS questionnaires. All responses were anonymized, and participants provided consent before answering each questionnaire.

Fig. 2. Questionnaires addressing the four principles of WCAG 2.1. Each block has questions focused on one principle.

2.2 Use of Automatic Tools

In our assessment of Canvas and Blackboard LMS, we also used automatic evaluation tools. We initially selected four free tools: AccessMonitor, AChecker, AxE, and WAVE. Selection criteria included their frequency of use, citations in literature, and user-friendliness. Tools lacking the capability for direct HTML code evaluation were excluded as the LMS necessitated login credentials, with tool inputs requiring links to access pages. Consequently, we employed WAVE and AxE to scrutinize the LMS.

We observed that these tools could not assess image, video, or audio content compliance with WCAG guidelines or criteria. Evaluating such media files required individuals' knowledge about the guidelines and content [2].

Using WAVE, we assessed Perceptibility, Operability, and Comprehensibility by evaluating Errors (issues impacting end users), Alerts (requiring revision like redundant links), Features (additional resources used with pages, such as screen readers), and Structural Elements (improvements for organization and navigation). ARIA attributes, closely tied to the robustness principle, were evaluated by WAVE but may vary across browsers and operating systems, leading to non-homogeneous results. Consequently,

we omitted ARIA attribute analysis from WAVE reports, thereby excluding robustness assessment using WAVE. Subsequently, we utilized the AxE extension to inspect accessibility related to general aspects of WCAG 2.1 and Sect. 5 08 (an amendment to the US Rehabilitation Act of 1973), presenting total problems indicated directly in the code.

Our analysis relied on reports generated by both tools, evaluating three types of content for each LMS: (i) the homepage encompassing all courses (referred to as E1), (ii) the homepage of a selected course with all modules (E2), and (iii) the homepage of a course module (E3).

3 Results

In this section, we showcase the outcomes gleaned from both the questionnaires and the reports generated by the automatic assessment tools. Following this, we delve into discussion comparing the insights garnered from the questionnaires with those derived from the automatic tools.

3.1 Questionnaires

A total of 134 students with disabilities (SwD) participated in the survey, with 68 responding via Canvas Learning Management System (LMS) and 39 via Blackboard (BB) LMS. The combined responses from Canvas and BB formed the Global Group (GG). Furthermore, 27 students responded to both platforms, referred to as the Restricted Group (RG). Computer Science students were 24, comprising only 8% of the sample, but they represented the majority in the RG.

Participants identified themselves as having disabilities such as Vision and Related Functions (39%), Neuromusculoskeletal functions (23%), Hearing and vestibular functions (9%), Global mental functions (2%), Developmental Disorders (2%), and (25%) unspecified disabilities.

SwD reported an average age of 42, with 38% being primary financial providers for their families, 11% not contributing financially, 66% being parents, 37% having a high school diploma as their highest educational level, and 44% using mobile devices with Android or iOS operating systems. Cell phones and computers (laptop or desktop) were the most used devices, while tablets were less common. The internet was primarily used for social networking and news, with gaming being uncommon.

Regarding assistive technologies, students reported using screen magnifiers, contrast adjustment tools, speech technologies, pointers, virtual or adaptive keyboards, and adaptive phones. 53% used at least one assistive technology, 22% used two or more, and 25% did not use assistive technologies even though they used LMS. Average scores for each principle in each LMS questionnaire were calculated. The results are presented in Fig. 3 and Fig. 4, where each principle is represented as a line in a direction labeled PE (Perceivable), OP (Operable), CO (Understandable), and RO (Robust).

Figure 3 displays scores for GG (N = 107, 68 from Canvas and 39 from BB) and RG (N = 54, 27 from each LMS). Figure 3(A) suggests that Canvas is generally more favored for the general principles, as perceived by the GG, while both LMS had similar overall ratings for RG. Conversely, Fig. 3(B) indicates that both LMS received comparable

overall ratings from the RG. It's noteworthy that during our survey period, students were transitioning from using Canvas to the new LMS, BB.

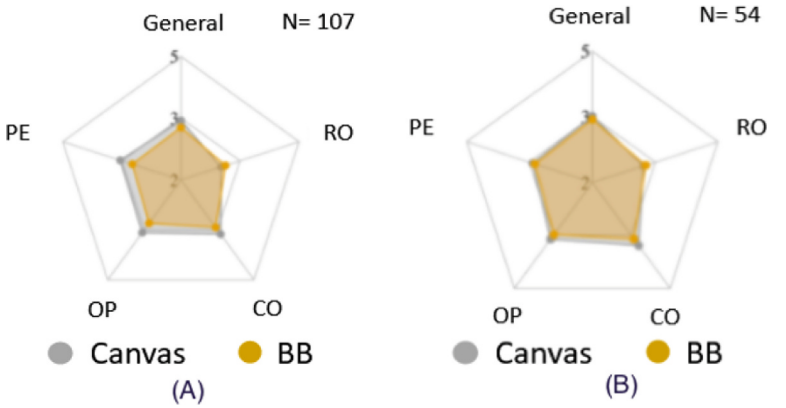

Fig. 3. Scores for each LMS considering the principles of WCAG, for GG (N = 107) and RG (N = 54).

We further analyzed the LMS scores concerning users and non-users of assistive technology. Figure 4(A) presents the scores for users of assistive technology in the GG (53% of 107 participants, approximately 57), while Fig. 4(C) exhibits RG, considering 27 participants with answers from both LMS totalling 54. Ratings among users of assistive technologies indicate that BB holds certain advantages over Canvas. However, ratings for BB are slightly lower than Canvas among those who do not use assistive technologies, as depicted in Fig. 4(B) and (D). This outcome suggests that users familiar with assistive technology tend to prefer BB.

3.2 A Subsection Sample

The AxE and WAVE automated tools detected that certain elements within the LMS webpages failed to meet at least one of the four WCAG principles (PE, OP, CO, and RO). The accessibility issues identified by both tools corroborated concerns raised by previous authors [2, 5, 12].

Table 1 outlines the accessibility violations observed in Canvas and BB using the WAVE tool, with 248 and 180 violations, respectively. For reference, we used E1, E2, and E3 to denote the main homepage for all courses, the homepage of a specific course, and the module homepage, respectively. The violations primarily pertained to structural elements and alert messages, followed by contrast issues, errors (such as breaks and pauses), and resource-related concerns. The significant number of alerts underscored the necessity for enhancements in the user interface to ensure greater user-friendliness and ease of navigation. The structural element issues directly impacted the usability and the perception of the displayed content. It is imperative to address these violations to enhance the overall accessibility of both LMS platforms.

In general, according to the WAVE tool, Canvas had more violations. Furthermore, both LMS had more alert message violations and structural violations than resources violations and errors. The assessment tool indicated the large number of contrast violations in Canvas.

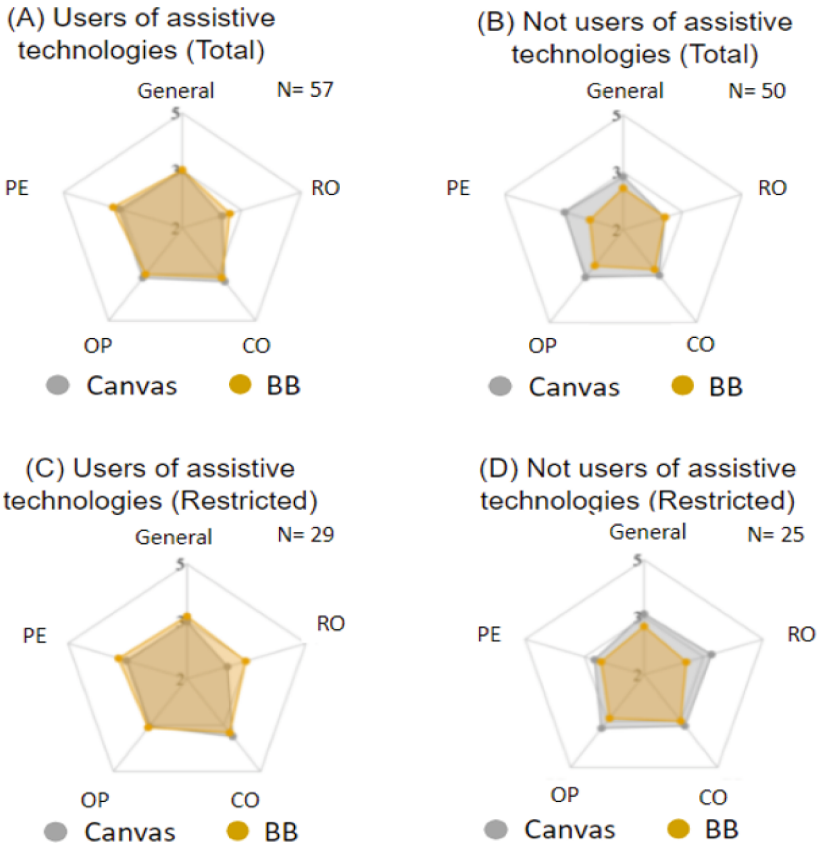

Fig. 4. Scores for each LMS considering the principles of WCAG, for two groups: users or non-users of assistive technologies. (A) Users of assistive technology in GG; (B) Non-users of assistive technology in GG; (C) Users of assistive technology in RG; (D) Non-users of assistive technology in RG.

Similar to the WAVE tool, AxE evaluated each page element independently without taking into account ARIA attributes. AxE categorized violations into critical, serious, moderate, minor, and requiring revision, with critical and serious violations aligned with WCAG principles. Moderate violations were not directly linked to WCAG but were still regarded as beneficial practices for accessibility. Our examination revealed numerous violations in both Canvas and BB that require prompt attention to enhance accessibility for students with disabilities (SwD), enabling them to utilize the LMS more effectively to meet their learning requirements.

Table 1. Accessibility violations in Canvas and Blackboard by the WAVE.

Violations	Canvas	Blackboard
	E1 E2 E3	E1 E2 E3
Errors	3 9 9	2 2 8
Contrast Violations	20 10 0	2 2 2
Alert Messages	59 23 20	31 31 28
Resource Violations	6 2 3	4 4 4
Structural Elements	24 34 26	18 21 21
	112 78 58	57 60 63

Table 2 illustrates that Canvas had 191 violations, whereas BB had 52 violations. The majority of found violations were related to contrast, with 166 for Canvas and 28 for BB. These violations, though not categorized as critical, serious, moderate, or requiring revision, still warrant attention, albeit less urgently. Canvas exhibited more critical violations (9 compared to 5 for BB), while BB had more serious and moderate violations (10 serious and 6 moderate for BB, and 8 serious and 4 moderate for Canvas). Additionally, BB had a few minor violations (4) that were absent in Canvas. Overall, both LMS platforms require enhancements to address the identified accessibility issues.

According to the AxE analysis, Canvas had critical violations concerning images lacking textual labels. Serious violations included frames without names and links lacking text descriptions. Moderate violations were related to the order of headers. No minor violations were detected. The tool identified numerous contrast violations and recommended revisions for two links sharing the same name. In summary, the tool advised revisions to ensure all images have descriptive labels, embedded videos include descriptive subtitles, links feature recognizable texts, headers follow a descending order, contrast is improved, and links with identical names are revised to serve the same purpose.

Regarding BB, AxE detected critical violations such as images lacking text, restrictions on resizing and zooming, and non-standard button elements. Additionally, serious violations were identified for link text and frames lacking names. Moderate violations encompassed concerns related to the institution logo overlay, missing or unclear bookmarks, and the order of headers. Minor violations included repeated IDs for focusable active elements and headers that were blank or indistinct. AxE suggested revisions to enhance background contrast and ensure that all images have descriptive text while ensuring links feature recognizable text.

Table 2. Accessibility violations in Canvas and Blackboard by the AxE.

Violations	Canvas	Blackboard
	E1 E2 E3	E1 E2 E3

(*continued*)

Table 2. (*continued*)

Violations	Canvas	Blackboard
Image Violations (C)	0 2 9	1* 0 1
Bottont Violations (C)	0 0 0	2 0 0
Zoom Violations (C)	0 0 0	0 0 1
Link Text Violations (S)	0 7 2+	2 1 1
Nameless Frames (S)	0 1 0	0 0 6
Bookmark Violations (M)	0 0 0	1 0 3
Header Violations (M)	0 0 4	1 0 1&
Repeated ID (M)	0 0 0	0 1 2
Contrast Violations (DR)	27 95 44	9 8 11
	27 105 59	16 10 26

Label: * moderated violation due to overlay of logo image. + revision due to a link with the same name. & minor violation due to the empty header.

4 Discussions

Upon analyzing the results, it was apparent that both Canvas and BB require adjustments to improve their accessibility aligned with WCAG 2.1 principles. We identified common violations, such as poorly described links, critical logical page organization, and inefficient contrast. Besides this accessibility assessment study, we conducted usability tests on both LMS's [7]. Similar accessibility and usability issues were highlighted by other researchers in higher education systems [5, 11], who also used automatic tools to identify common errors [11].

Both WAVE and AxE were used to assess contrast problems, while WAVE also used to quantify the number of contrast errors per page. References [3, 5] and [12] used WAVE to identify contrast issues, indicating that the highest incidence of contrast errors was in the control area of Canvas. Due to differences in website design, there is no compatible mechanism to control color contrast, brightness, and other features, which is a common inconvenience. Reference [3] reported that Portuguese universities had significant accessibility violations, including contrast, alternative texts for images and buttons, and links without visible texts [3]. Likewise, our study revealed similar problems with Canvas and BB and found the same violations reported by other education institutions. However, the frequency and number of violations varied widely, depending on the frequency of images, videos, and links in the evaluated system.

We believe that solving the common violations found in both Canvas and BB LMS's could improve user satisfaction and lead to higher scores in the questionnaires. However, users may perceive accessibility issues differently from automatic tools, and problems related to the understandable principle, such as language and zoom, may also affect users significantly. In our study, users with visual impairments and related functions were prevalent, and problems related to contrast, color, and zoom could have a significant

impact on our community. Therefore, it is crucial to not only identify where violations occur in the source code, but also understand how they affect the user.

In summary, our evaluation using both automatic tools and questionnaires based on the WCAG principles highlights the urgent need to improve accessibility in LMS's. The questionnaires provided valuable insights into the experiences and understanding of the LMS's by different SwD groups, while the automatic tools identified violations that may have been missed by human evaluations. Thus, the tools were complementary in evaluating LMS's accessibility.

5 Final Remarks

This study involved the distribution and analysis of questionnaires to students with disabilities (SwD) to assess their satisfaction with Canvas and BB LMS's and whether their perceptions aligned with accessibility WCAG principles. The resulting score from the questionnaires for both LMS's was approximately 3, indicating a moderate level of satisfaction. Notably, SwD who used assistive devices rated BB higher than those who did not, while those without assistive technology preferred Canvas. However, the differences of satisfaction were small.

In addition to the questionnaires, automatic tools were used to evaluate possible accessibility violations in the LMS's pages and source codes based on WCAG 2.1 principles. The tools, AxE and WAVE, identified violations in all principles, highlighting the need for improvements in both LMS's to increase satisfaction levels. The questionnaires and automatic tools were complementary in providing different perspectives on accessibility evaluation.

According to university administrators, the switch to the new LMS had a positive impact due to lower costs, stability, unlimited service usage time, and support for high demand for services. Our study revealed that SwD's perception of accessibility was similar for both LMS's, making it difficult to determine which one had better accessibility. Only users of assistive technologies showed a preference for BB. Overall, SwD did not see significant improvements in accessibility after the switch. It is worth noting that both platforms had similar violations and problems. The automatic tools identified numerous violations in both LMS's, with Canvas having more violations than BB (mainly background contrast violations).

Although our study was a case study, it contributes to the understanding of the evaluated systems, raises questions about the applicability of the results, and opens possibilities for improving the efficiency, effectiveness, and continuity of these systems. Other contributions were: (i) the identification of the main accessibility problems on both LMS's, and (ii) the description of a method that can be reused for accessibility assessment, especially regarding LMS's. It can be used to evaluate systems in a unique or comparative manner.

In the future, we intend to (i) evaluate the impact of the improvements made to the LMS's based on our findings; (ii) examine how the LMS's support different tasks, such as the process required to complete certain objectives (e.g., uploading homework, watching videos, etc.); (iii) develop independent assessments to evaluate the functionality of user interface design elements that can be configured; (iv) conduct new evaluations

by modifying parameters, such as scales and the WCAG principles used for the analysis; (v) expand the number of interviews with SwD; (vi) include more LMS platforms in the study to offer a broader view of the market's accessibility options and potentially identify best practices, (vii) assess changes in SwD satisfaction and LMS accessibility over time, especially after implementing suggested improvements to check progress and effectiveness; (viii) add an analysis of the cost implications of switching LMS or making accessibility improvements in order to offer a more comprehensive view for decision-makers; and (ix) consider how the previous findings apply to or differ from experiences in other countries aiming to enhance relevance and applicability internationally.

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Emerging Technologies in the Public Sector

Impact on Anti-Corruption Strategies

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Abstract. Corruption, as well as other illicit financial flows, cost countries a lot of money, raising the question of what role technologies, particularly emerging technologies, can play in combating this corruption. In this sense, the present study aims to carry out a narrative literature review about the relevance that emerging technologies could play in combating corruption in the public sector. We trying to answer the research question: "is there evidence that emerging technologies have an impact on the fight against corruption in the public sector?". The analysis of works allows us to think that some emerging technologies (e.g. artificial intelligence, blockchain, cloud computing, machine learning, etc.), as they are less dependent on human-machine interaction, could give a new boost to anti-corruption fight. The analysis of works also allow us to concluding that emerging technologies could play a decisive role in reducing corruption. However, some studies also warn of the emergence of new forms of corruption because of the use of emerging technologies.

Keywords: corruption; emerging technologies · public sector · narrative literature review

1 Introduction

Corruption, bribery, theft and tax evasion, as well as other illicit financial flows, cost developing countries approximately $1.26 billion per year. This value roughly corresponds to the combined value of the economies of Switzerland, South Africa and Belgium and would be enough to support the 1.4 billion people who survive on less than $1.25 a day above the poverty line and maintain them at that level for at least six years.

Sadik-Zada, Gatto and Niftiyev [1] developed a study that addresses the question of the existence of an essential relationship between the development of electronic government and petty corruption. Carrying out a quantitative analysis, these authors verified that there is a relationship between the development of electronic government and the

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reduction of petty corruption in the provision of services by the public sector to citizens. These authors also found that, in addition to the development of electronic government, the increase in the level of per capita income also leads to a lower rate of corruption, with the effect of electronic government, on average, being greater than the effect of income. Furthermore, the study concludes that a higher level of political rights and civil liberties can also lead to significant improvements in bureaucratic quality in terms of minimizing bribery.

Based on the aforementioned study, it seems possible to assess that information and communication technologies, used in the implementation of business processes, within the scope of an electronic government strategy, can have an impact on minimizing problems associated with corruption in the public sector. However, Köbis, Starke and Rahwan [2] state that these technologies facilitate the digitalization of business processes related to the acquisition, provision of public services online and the publication of open data from government bodies, but present limitations in the fight against corruption for not acting autonomously.

According to Sanka and Cheung [3], another reason why current solution based on traditional information and communication technologies, present weaknesses in the fight against corruption, is that they have not yet managed to free themselves from the significant influence of human beings. However, some of the so-called emerging technologies, such as Blockchain technology, are not subject to the jurisdiction of central regulatory entities and intermediaries, offering increased protection over data and providing greater transparency and auditability.

A technology can be defined as an emerging technology if it combines some social characteristics (e.g., leverage, ascendancy, ambivalence, materiality, etc.) and some artificial characteristics (innovation, rapid growth, coherence, impact, ambiguity, etc.) in the context of a certain time frame [4]. These technologies have been changing the way we live, work and spend our free time, with the capacity to influence, to some extent, our expectations about the way government bodies, central and local, can and should improve health care, dealing with climate change, providing unemployment benefits, managing public works or educating our children. Although this may seem like an idealized version of what our future could be, we are already experiencing situations that closely resemble this future reality [5].

There are several lists with reference to the main emerging technologies, such as those from the World Economic Forum and Scientific American. These lists are regularly reviewed and published annually by various organizations. Some of the most recent examples of emerging technologies include robotics, blockchain, drone technologies, as well as various technologies in the medical and environmental areas. Artificial intelligence and support for automated decision making are also some of the emerging technologies frequently mentioned. In fact, there is no single list of specific technologies defined as emerging. Fixing in time something that by nature continually emerges would be contrary to the principle of emerging technologies. On the contrary, these technologies are dynamic, interacting with their users and processes [6].

Also Kalampokis, Karacapilidis, Tsakalidis, and Tarabanis [7] are of the opinion that in general, emerging technologies are a dynamic concept that comprises an evolving list of information and communication technologies, with a continuous impact on action

and human interaction. Some representative examples of these technologies, applied and tested in the public sector, include blockchain, artificial intelligence, semantic technologies and the internet of things.

The panorama presented above motivated the carrying out of the present study, which aims to carry out a narrative literature review [8] about the relevance that emerging technologies could play in combating corruption in the public sector. Therefore, to carry out this research, we started by formulating the following research question: "is there evidence that emerging technologies have an impact on the fight against corruption in the public sector?". To obtain an answer to this question, the following objective was defined "to identify and analyze work on emerging technologies related to the fight against corruption".

The remaining work is organized as follows: In Sect. 2 the methodology is presented, in Sect. 3 the narrative review of the literature and in Sect. 4 the conclusions of the review carried out.

2 Methodology

From what was mentioned above, emerging technologies have had a strong impact on organizations at different levels (e.g. economic, cultural, ethical). In this study we seek to obtain evidence of the impact of emerging technologies on anti-corruption behavior [9]. There is not yet enough research on this topic to facilitate the use of a research protocol. Therefore, we will evaluate the state of the art by carrying out a narrative review of the literature.

The objective of a narrative literature review is to objectively report the state of the art on a topic based on previously published work. A narrative literature review can provide interested parties with a comprehensive overview in perspective. In this type of review, several sources of information are researched and the results considered relevant are summarized in a single article. Thus, a vast amount of information is gathered and presented in such a way that interested parties can clearly understand it and understand the topic analyzed [10, 11].

The information used to prepare this article was collected between January 22nd and 26th, 2024. The definition of the parameters used in the bibliographical research, to make the study viable, considered that there are three types of narrative literature review: (1) review of editorials; (2) review of comments and (3) review of articles, and we chose to review articles. Carrying out an exhaustive review of all articles that have any type of relationship with the topic of study would be a difficult task. Therefore, the limits defined at this stage must be broad enough to ensure that all relevant studies can be selected, but restricted enough to concentrate the effort [10]. In this work we use the following terms for research: "emerging technology"; "emerging technologies"; "emerging technology"; "emerging technologies"; "corruption" and "ethics" in conjunction with the term "public sector".

According to Green, Johnson and Adams [10], the primary concepts or themes of the topic under study must be transformed into unique words, which can be used as search terms. Furthermore, it must be ensured that the search terms used are recognized by the vocabulary of the repositories of the scientific area in which the topic falls. Most indexes have a keyword search function that will find synonyms for the search term.

3 Narrative Review of Literature

The use of digital technologies to prevent corruption is a new interdisciplinary concept that draws on both the knowledge of legal experts and the knowledge of experts in emerging technologies. However, reckless use of these technologies can have significant negative social and political consequences. Therefore, the theoretical development of this area is an important step towards harmonizing law with the use of digital technologies, particularly emerging technologies [12].

The usefulness of different forms of technology (traditional and emerging) to combat corruption is gaining increasing relevance, including by organizations such as the Organization for Economic Co-operation and Development (OECD), Asia-Pacific Economic Cooperation (APEC), the World Economic Forum (WEF), the International Monetary Fund (IMF) and the United Nations Development Program (UNDP) [13].

The strategies carried out by various government bodies in the public sector, both central and local, to implement electronic government have also been enhancing the effort to prevent corruption. The anti-corruption campaign can be considered a common program between government bodies and citizens. This program has evolved over time and has adapted to the global conditions in which we have been living. The majority of citizens consider that e-government implementation strategies are favorable to reducing the risk of corruption cases [14].

The integration of new technologies, such as data analytics and artificial intelligence, makes it possible to increase the effectiveness of organizations that use them, allowing rigorous analysis of vast and heterogeneous sets of data, making it possible to identify suspicious patterns and atypical behaviors. In this context, Blockchain technology can be considered as a promising tool to guarantee the integrity and transparency of transactions and financial records, hindering the possibility of data manipulation [14].

According to Davis and Lennerfors [15], contemporary understandings of blockchain technology and corruption theory allow us to discern that there is high potential for multinationals to use this technology to manage and control their operations in emerging markets. If this happens and being blockchain technology one of the emerging technologies with the potential to fight corruption, there are conditions under which this technology can also be used in internal transactions and minimize the risk of fraudulent activity being triggered.

Furthermore, the provision of public data through open data platforms and the promotion of transparency in government bodies increase civil society's scrutiny of public organizations, thus strengthening control over public expenditure. These measures facilitate the deterrence of corrupt practices and hold public agents responsible for their actions, increasing levels of accountability [16].

Malik and Froese [17] systematically reviewed the most recent academic and political literature that seeks to clarify some of the impacts that information and communication technologies have on corruption. The tools analyzed include digital public services, crowdsourcing platforms, whistleblowing tools, transparency portals, big data, blockchain technology and artificial intelligence. The analysis carried out by these authors thoroughly examined some evidence about its effectiveness, some of its disadvantages and also the potential misuse of some of the technologies analyzed that can help to promote corruption. Among its conclusions, it seems clear that different

technological advances and digitalization have had widespread effects on corruption, introduced new opportunities and challenges to simultaneously minimize and leverage corruptive behavior.

According to Inuwa and Ononiwu [18], information and communication technologies have been adopted, particularly when associated with the implementation of e-government strategies, for anti-corruption purposes. This is due to the need for transparency in public sector accountability throughout the world. The introduction of these anti-corruption initiatives, associated with information and communication technologies, through the implementation of strategies associated with electronic government, in the developing economies of Sub-Saharan Africa and in developed countries, has given rise to another form of corruption.

Corruption, the misappropriation of authority, resources, trust or power to obtain private or institutional gains, has a particularly relevant impact on public contracts, where it is estimated that 10% to 30% of public spending on procurement is lost due to poor quality. Management and corruption. Some technological solutions, based on emerging technologies, have been gaining relevance due to their potential to combat corruption. In the context of these technological solutions, the use of mobile devices, the use of machine learning to optimize the supply chain and blockchain technology can be mentioned [19].

Adam and Fazekas [20, 21] also understand that emerging technologies can potentially generate new opportunities for corruption, related to the dark web and cryptocurrencies or simply through the unethical use of technologies used in an unethical way. Well-intentioned, as in digital public services. For information and communication technologies to be effective in controlling corruption, there is still a strong dependence on the attitude of political agents, public administration bodies and civil society groups. Without the commitment of these actors to minimize the problem, it will be very difficult to minimize the risk of fraudulent attitudes in environments that resort to technological solutions based on the use of emerging technologies.

Lack of training was also identified as a problem due to lack of experience and knowledge in using information and communication technologies to prevent and investigate corruption [22].

Sabani et al. [23], developed work on the concept of governance, analyzing the relevant characteristics of governance in developing countries and the role of governance supported by information and communication technologies in combating corruption in Indonesia. These authors concluded that it is necessary to implement good governance facilitated by information and communication technologies to support the eradication of corruption, in the specific case of Indonesia.

Investment in information and communication technologies represents 50% of all European productivity growth. Recognizing its importance, in the Horizon 2020 program, the European Union set aside 16 billion euros for research in this area. In addition to this public investment, there is also significant private funding in research and innovation. The scope of this financing and its social consequences indicate that innovation must be accompanied by the development of appropriate mechanisms that allow the social and ethical consequences of emerging technologies to be identified [24].

Carsten and Eke [25] carried out a study in which they explored the ethical issues raised by ChatGPT beyond current debates about authority, demonstrating the potential of application and approaches to the ethics of emerging technologies. They also highlight a wide range of relevant ethical concerns that go beyond current discourse. This is useful for academics concerned with ethical issues within artificial intelligence, but also for anyone else interested in ethical issues. Overall, they advocate applying a holistic ethical perspective to continually guide discourse and action around impactful emerging technologies.

Public procurement is a process through which the State orders different types of services and therefore spends taxpayers' money. Therefore, they have the obligation to question whether their money is spent in compliance with legal regulations and whether the State is obtaining the best service or goods for a real price or whether there is some form of corruption that could be generating waste of public money. Corruption in public procurement is defined as the abuse of power to obtain private profit. The most common types of fraud and corruption in procurement are bid rigging, collusion between suppliers and employees, and collusion between suppliers. Technology is sometimes only as good as specialized resources for monitoring these procedures. Furthermore, the ability to quickly engage the right combination of people, processes and technology can limit the potential damage from fraud or corruption [26].

One of the greatest challenges posed by emerging technologies is related to ethical issues. As we do not know the future, we cannot know what ethical questions will arise when technology is fully developed and rooted in society. Questions about its nature, use and social consequences are still open. For this reason, many ethical issues regarding different emerging technologies cannot yet be identified or analyzed reliably. We can speculate about future applications and uses, but as history has shown, speculation about the future use of technology is often wrong. This means that we may end up wrongly exploiting the potential of a certain technology, namely its use for purposes associated with corruption. Thus, the study of ethical issues in the research and development phase of new technologies in order to anticipate possible uses with negative consequences for society still presents many gaps [27].

4 Conclusion

The analysis of works related to the theme developed in this study allows us to think that some emerging technologies (e.g. artificial intelligence, blockchain, cloud computing, machine learning, etc.), as they are less dependent on human-machine interaction, could give a new boost to anti-corruption fight.

It also allowed us to identify evidence that emerging technologies have an impact on the fight against corruption in the public sector, and this impact is usually positive. However, there are also some studies that warn of the misuse of emerging technologies creating new forms of corruption, particularly due to a lack of knowledge of the impact of the widespread use of emerging technologies.

It can also be concluded that the assessment of the possible impact of emerging technologies on mitigating corruption must be done through an interdisciplinary approach. Minimizing the risk of corruption through the use of emerging technologies can also

have the relevant counterpart of increasing the performance of institutions that implement anti-corruption programs using digital technologies. Furthermore, the use of an open data platform making public data available leads to increased transparency and a better relationship between citizens and government bodies. All of this requires adequate levels of digital literacy. Therefore, a strong commitment must be made to training all interested parties so that they can understand the world in which we live.

It is imperative not only to understand the impact and benefits of emerging technologies, but also to look and understand their possible ethical problems, contextually and at the level of their application, both in developed and less developed countries [28].

While there are tools available to combat corruption and fraud in the context of improving transparency in public administration, enabling better financial management, establishing procedures to resolve conflicts of interest and other solutions used in forensic auditing and law enforcement, they are also now emerging digital technologies that can more systematically combat corruption in specific sectors [13]. Also, according to the same authors, innovative technologies that are now being positioned to combat corruption include big data analysis, mobile and website applications, artificial intelligence and machine learning, blockchain, technology to combat online disinformation and civic technologies used to encourage greater participation in government (e.g., e-government and open government initiatives).

It is clear that technologies will not act as a "silver bullet" to fully address the multifaceted and complex nature of global corruption [13]. However, J. Li, W. Chen, Q. Xu, N. Shah, J. Kohler, and T. Mackey [13] demonstrate the potential usefulness of big data and machine learning approaches to shed additional light on the corruption, in the hope of enabling the development of next-generation anti-corruption solutions. It is hoped that technologies can be used as a positive force to combat corruption, which continues to act as a threat to human development, health and prosperity.

In this way, the narrative review of the literature carried out allows us to respond positively to the research question-"is there evidence that emerging technologies have an impact on the fight against corruption in the public sector?". However, this study also made it possible to identify new corruption risks resulting from the use of emerging technologies.

This study's main limitation is the fact that it does not collect empirical data to support its conclusions, and it is recommended, as different technologies are used, to assess their impacts through surveys or through concrete data from cases of corruption known.

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A Customizable Escape Game-Like Based on Computational Thinking Categorization

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Abstract. This paper describes a customizable educational escape game-like project that aims to support Computational Thinking (CT) learning and evaluating processes. Recognizing the importance of fostering computational thinking skills in basic education, this work focuses on the design and development of a customizable serious game in a virtual reality environment, based on escape room concepts, containing various minigames designed to promote CT. The collection of minigames is based on Bebras challenges, which can be regarded as unplugged activities originally designed to stimulate students' interest in computer science. The sequence of minigames follows categorical flows, defined so that specifics informatics domains and CT skills are trained or evaluated. For this purpose, each minigame implemented is associated with informatics domain, CT skills (abstraction, algorithmic thinking, decomposition, evaluation, generalization), level of difficulty and student's age group, enabling the environment to be customizable. The project is being developed using Unity 3D framework and next steps include testing, conducting case studies in traditional classrooms and assessing the outcomes provided by students and teachers.

Keywords: Computational Thinking · Escape Game · Serious Game

1 Introduction

Jeanette Wing [1] described Computational Thinking (CT) as a "way of solving problems, designing systems, and understanding human behavior by drawing

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on the computer science fundamental concepts". She pointed that it involves concepts as problem decomposition, data representation and modeling, as well as binary search, recursion, and parallelization. She also stated that CT is a fundamental skill for everyone, as it can be understood as a thought process by which problems are represented in such a way that their solutions may be evaluated using information processing techniques. Since then, there has been growing interest in CT, as evidenced by several recent reviews covering its definitions, methods of assessment and educational initiatives [2–5].

These ideas are associated to a range of attitudes and skills (or practices), including creating computational artefacts, testing and debugging, collaboration and creativity, and the capability to address open-ended problems [6]. This scenario frames CT as a fundamental competence for an informed citizen capable of coping with societal challenges. CT also bears potential as a means for creative problem solving and innovative approaches in several disciplines. It therefore has a crucial role to play in basic education [7].

In Brazil, the integration of CT into curricula has occurred through the inclusion of computer science-related topics, disciplines exploring it with technologies, and its incorporation as a cross-cutting content [8]. This integration predominantly involves computational tools, plugged-in and unplugged approaches in studies and educational practices. Unplugged activities emerge as an alternative to overcome the lack of technological equipment in public schools, as they consist of a set of practical and engaging activities for learning CT without using a computer. They usually promote learning through board games and playful activities.

To assess students' knowledge and skills in CT, one relevant initiative is the Bebras International Challenge in Informatics and Computational Thinking (bebras.org). It is an international CT contest, created in 2004. Since its origin, Bebras has been promoting interest and learning of computer science and CT for students globally. The challenges are composed of short tasks relying on unplugged activities [9]. Each task engages student's attention through images and does not require any previous computing knowledge [10]. Bebras.pt is an edition of the contest for Portuguese-speaking countries. In only four editions, it experienced remarkable growth, increasing from 5,469 participants in 2019 to 77,853 in 2022. Each challenge is associated with a specific year of education level, ranging from the third to the twelfth year of schooling, and has a sequence of fifteen tasks of three different difficulty levels (easy, medium, hard).

There is evidence that Bebras challenges can be utilized in school curricula as effective tools to promote problem-solving skills and CT in children and young people [11]. In this context, the present work proposes a virtual reality serious game that incorporates the tasks contained in the Bebras challenges as minigames within it. Depending on the purpose (evaluate or practice), education level and on the desired informatics domain and CT skills, a teacher is supposed to customize the game with the appropriated minigames. Given that the beaver is the mascot of Bebras, the game features it as the main character in a dense closed forest based on an escape room model. The goal is to collect all

the rewards (picnic essentials) obtained through playing the minigames in order to find the exit to the picnic area.

The use of escape rooms for learning computing and CT skills has demonstrated promising results [12], as they provide an immersive environment for learning and problem solving. Participants find themselves "locked" in an artificial environment, where they must solve puzzles to break free from their "entrapment". The proposed idea aligns with the trend of promoting a critical and reflective education integrated into a digital world to help students to learn by using the technology with which they live daily. For this purpose, teachers are challenged to create activities that are effective by combining available tools and methodologies as CT, programming, robotics, teamwork, and critical thinking [13].

Serious games are designed not only for entertainment but also to transmit knowledge or to address a specific issue. Gamification in education is achieved using game elements in educational activities and processes, such as: competitions, achieving levels or points, solving challenges and awarding rewards. The incorporation of game mechanics enhances the overall experience, making the processes of learning or problem-solving more appealing and engaging [14]. This paper describes the design and development of a customizable escape game for practicing CT skills, in different levels of education. The game design methodology and technical aspects of the implementation are described and, finally, perspectives for future development of the escape game-like are presented.

2 Background

2.1 Computational Thinking

Computing can be defined as any activity that develops and uses computer technology resources. Computational thinking applies the problem-solving ability of computer to human thinking system and uses it to solve problem in various fields. It consists of four pillars [1]:

- Decomposition: ability to break down a complex task into smaller manageable ones.
- Abstraction: ability to choose an appropriate representation of a problem to develop a solution that is applicable in diverse situations.
- Pattern recognition: ability to search through a large amount of data to identify shared patterns.
- Algorithmic thinking: ability to find a promising way to solve the problem step by step.

All four pillars hold significant relevance and operate independently during the process of formulating computationally viable solutions. The increasing significance of studies pointing to the development of CT skills as a substantial contribution to students' education is noteworthy. In this context, the development of CT is considered one of the fundamental pillars of human intellect, along with

literature, writing, and arithmetic, as it, like these, serves to describe, explain, and model the universe and its complex processes.

Educational policies for the development of CT are being implemented at international level. In Brazil, the Basic National Core Curriculum (BNCC) establishes the learning rights of all students throughout basic education and mentions the development of CT as part of this process [15]. Complementing the BNCC, the Brazilian Computer Society elaborated a document named "Standards for teaching computing in basic education" to establish specific competencies in computing to be addressed in national basic education, including CT [16]. Also, the presence of CT at the early age of education is a factor that allows girls to be in touch with technology in a meaningful and enjoyable manner, cooperating to balance the male and female presence in science and technology [17].

Several tools and methodologies are employed to teach CT including storytelling and creative projects, algorithms and problem-solving challenges, game-based learning, educational platforms, coding and programming languages, robotics and physical computing, collaborative learning, digital simulations and modeling, and finally, unplugged activities. They play a crucial role in supporting CT learning by offering possibilities of concrete and practical applications, feedback, engagement, and motivation.

The idea of the Bebras annual challenge on Informatics was proposed by Prof. Valentina Dagienė of Vilnius University in 2004. Currently, the Bebras network includes more than 40 countries. In each country, the community relies on two teachers who are responsible for submitting new tasks and may also organize the challenge [18]. It is held online, within school time, using contest management environments. The tasks are chosen from the approved annual task pool. A good task should:

- represent informatics concepts.
- stimulate computational thinking.
- motivate learning informatics.
- open a new knowledge area for students.
- facilitate a deeper understanding of technology.
- be short and solved within 3 min.
- present information independently from specific software.
- be interesting and funny.

Task authors should indicate difficulty level, grade and may use a two-level categorization system [18] to assign the informatics concepts and the CT skills that students may need to solve it. The CT skills are explained in Table 1 and informatics concepts are depicted in Table 2.

As an example, Fig. 1 shows a task proposed by the Russian delegation [19]. It demonstrates how graphs can be used to represent dependencies between items and allow students work mainly the decomposition skill: to solve the question for one kitten, they can first answer the same question for a coin, a ruby, and a crown. Table 3 shows the definitions for the two-level characterization.

The categorization system can also serve to promote the creation of assignments that encompass a range of computer science topics and CT skills. More-

Table 1. CT skills identification [18]

CT skill	How to identify the use of that CT skill
Abstraction	Removing unnecessary details; spotting key elements in problem; choosing a representation of a system
Algorithmic thinking	Thinking in terms of sequences and rules; executing an algorithm; creating an algorithm
Decomposition	Breaking down tasks; thinking about problems in terms of component parts; making decisions about dividing into sub-tasks with integration in mind
Evaluation	Finding best solution; making decisions about good use of resources; fitness for purpose
Generalization	Identifying patterns as well as similarities and connections; solving new problems based on already-solved problems; utilizing the general solution

Table 2. Informatics domains and keywords [18]

Domain	Keywords
Algorithms and programming (ALP)	Algorithm; binary search; brute-force search; bubble sort; coding; constants; divide and conquer; encapsulation; function; if conditions; inheritance; loop; operations *and*, *or*, *not*; variables, etc.
Data, data structures and representations (DSR)	Array; binary and hexadecimal representations; binary tree; character encoding; databases; graph; hash table; integer; information; list; queue; record; stack; string, etc.
Computer processes and hardware (CPH)	Cloud computing; grid computing; image processing; memory; operating systems; parallel processing; peripherals; priorities; registers; scheduling; sound processing; translator; turing machine, etc.
Communication and networking (COM)	Client/server; computer networks; cryptography; *e-commerce*; encryption; parity bit; protocols; security; topologies, etc.
Interactions, systems and society (ISS)	Classification; computer use; design; ethics; graphical user interface; interaction; legal issues; robotics; social issues, virus.

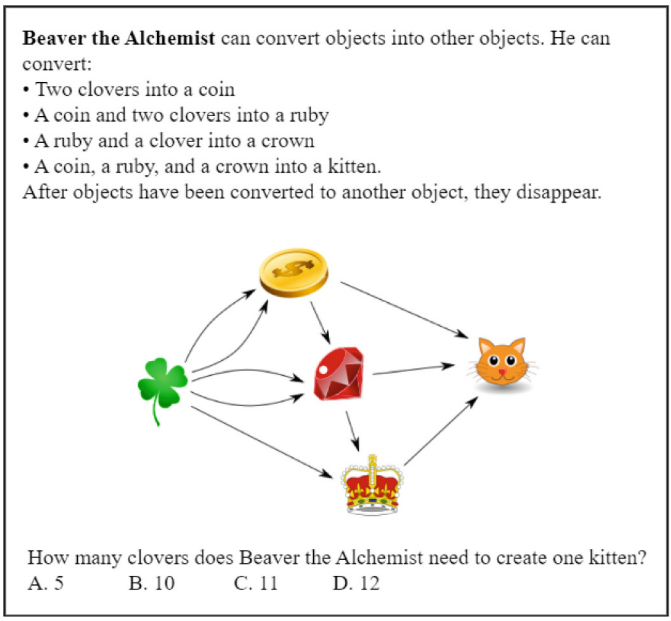

Fig. 1. Example of a Bebras task. Adapted from [19].

Table 3. Two-level categorization template example [18]

Task name	Informatics domain	Keywords (≤3)	CT skills (≤3)
Beaver the alchemist	DSR	Graph, schema, data structures.	Decomposition, algorithm thinking

over, it helps informatics teachers in deciding the lesson content and facilitates the efficient selection of tasks based on specific topics.

In this work, the two-level classification in [18] will be used to guide the selection of activities that should be part of the minigames within the escape game environment. By comprehending the activities and their classifications, the instructors can define a sequence of minigames suitable for the domain and CT skills they want to teach, according to the age group and the desired level of difficulty.

2.2 Educational Escape Room Games

Educational games are a subset of serious games that prioritize education over entertainment and facilitate a "learning by doing" approach, being used by any gender, ethnicity, and socioeconomic level [20]. These games provide students with a learning experience in an interactive environment that enhances engagement and motivation. Besides the game challenges, they can receive relevant feedback to support their learning process.

The primary advantage of educational games is the ability to adapt the educational practices to "digital natives", those individuals who use computer games and browse the Internet from a very early age. According to [21], games can play a crucial role in introducing programming to young students, as traditional methods are inadequate for their age group and do not effectively address challenges such as their limited attention span.

Escape rooms are interactive games in which players uncover clues, solve puzzles, and complete tasks within one or more rooms, aiming to achieve a specific objective, often escaping from the room, respecting the playtime limit. In [22], escape rooms are identified as motivating tools for learning computer networks and security, while [23] recognized them as engaging tools for teaching programming in higher education. One of the primary challenges facing escape room designers is crafting an engaging narrative and constructing a series of puzzles that align with it, which can be, for example, searching for hidden objects, solving word puzzles, deciphering codes, or assembling physical objects. For Educational Escape Rooms (EER), the puzzle-building challenge becomes more intricate, as teachers should integrate the content taught in classes, enabling students to apply the acquired knowledge to progress in the game.

Several relevant aspects need to be considered during the creation of an EER: participants, objective, theme, and specific puzzles. The work in [24] proposed some primary steps for developing an EER game, illustrated in Fig. 2.

Fig. 2. Main steps in developing EER. Adapted from [24].

At the starting point, the identification of learning needs is useful to consider: demographics and educational needs of the players, playtime limit, puzzle's level difficulty, game mode: competitive or cooperative, and number of players. The next step is needed to define the experience objectives and the game design, considering how to encourage active learning, communication, creativity, collaboration, and critical thinking.

The narrative development is a step where engagement and immersion must be regarded, as the story is the guideline to effectively apply the desired knowl-

edge as well as challenge and motivate players. The puzzles elaboration may consider one of the approaches: linear path, open path, or multilinear path [25], as illustrated in Fig. 3. In the linear approach, puzzles must be done in order, and the answer to a puzzle may help solve the next one. In an open path, puzzles can be solved in any order, without a defined starting task, but usually having a final one, that can be solved only after all others are completed. The multilinear approach allows the definition of many linear paths that can be followed in parallel to achieve the end of the game.

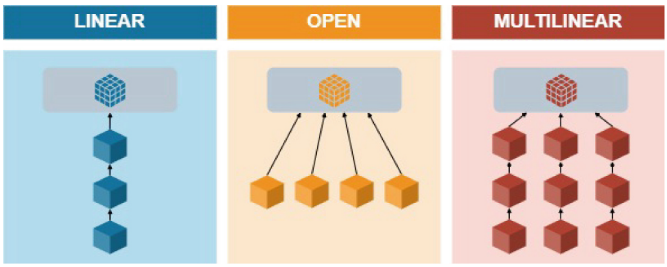

Fig. 3. Puzzle design flows. Adapted from [26].

According to [26], the most prevalent organizational method in 45% of the described games is multilinear. In this approach, a team or player is confronted with multiple distinct paths of puzzles simultaneously. Each puzzle path forms a sequence leading to a final challenge and it is possible to work on different puzzle paths at the same time. By presenting a subset of puzzles, the designer can initiate the game with simpler challenges and progressively introduce more intricate puzzles as players gain confidence and familiarity.

2.3 Serious Game Customization

The adaptive serious game responds better to players needs and backgrounds when context-based variations are considered [27]. This leads to a personalized training experience for each individual, emphasizing the versatility of adaptive serious games across various applications.

There are two main approaches to adaptation in the context of serious games: system-controlled adaptation and user-controlled adaptation [28]. System-controlled adaptation relies on real-time feedback to dynamically adjust based on player performance, while user-controlled adaptation allows players to independently customize their experience. Both approaches aim to accommodate individual characteristics. System-controlled adaptation operates autonomously, evaluating competence and learning progress at a micro-level, while user-controlled adaptation provides macro-level flexibility for customization, requiring configuration by players.

This proposal is centered around a customizable escape game-like framework, using user-controlled adaptation. It is designed for CT training and evaluation, allowing teachers to create instances tailored to diverse student levels, interest topics and skills.

3 Game Development and Design

To guide the development of the proposed customizable escape adventure, called The Beaver's Odyssey (TBO), the four steps in [24] are addressed in this section. For the first step, that is to identify learning needs, we spot CT teachers and students as the main participants, with the teacher being responsible for creating a game instance suitable for the educational context. The students must play the game individually, using their personal equipment, which can be a mobile phone. The parameters for defining the instance consider the students' educational level, the game target (training or evaluation), the desired CT skills (Table 1), the computing theme to be taught (Table 2), and the gameplay time limit. TBO combines game-based learning with the informatics domain of interest, allowing teachers to engage students in a more interactive and dynamic experience. The defined objectives (second step) are:

- Customizable game environment: Using the participant parameters, the game instance can either be generated automatically or, alternatively, the teacher can manually select the suitable minigames. Each minigame is classified according to the two-level CT categorization and age group.
- Task variety and complexity: A game instance organizes a diverse range of Bebras-based minigames that cover various aspects of informatics domains and CT skills. Teachers have the flexibility to accommodate varying proficiency levels within the selected age group.
- Interactive and immersive experience: The beaver is the main character, and it starts locked in a dense closed forest. The created environment must be visually appealing and interactive.
- Feedback and assessment: Considering the training or evaluation possibilities, the game must provide real-time feedback to students, highlighting areas of strength and areas that may need improvement. Also, an assessment mechanism that allows teachers to evaluate students' performance in CT skills is proposed.
- Accessibility and user-friendly interface: A user-friendly application for both teachers and students is required with clear instructions and intuitive navigation.

The third step has focus on the narrative, regarding engagement and immersion. TBO can be classified as an animal adventure fable, with a beaver as the main character, initially trapped in a dense and closed forest. Beavers are famous in literature and tales for the large dams they build to protect their subaquatic burrows. They can also modify their habitats by digging canal systems and selectively cutting down trees and shrubs. It is common to find references to beavers

as "natural ecosystem engineers". To compose the challenges that will outline the escape journey, each Bebras-based minigame incorporates storytelling elements related to the beaver's expedition. The rewards for succeeding the challenges are picnic essentials as food, beverages, picnic mat, basket, tablecloth, portable chairs, etc. The goal is to escape the forest to reach the picnic area, reunite with its family, and bring along the maximum possible items rewarded for the picnic.

In the fourth step, concerning puzzles, the minigames are defined and developed. For TBO, each minigame implemented is based on a Bebras task, and for that reason, it is associated to an age group, a level of difficulty (easy, medium, or hard), a list of 3 maximum CT skills (Table 1) and an informatics domain with keywords (Table 2). Those associations are crucial to articulate a minigame that is both useful and productive. Each minigame design incorporates all essential elements to achieve the desired goal while constraining its age range, complexity, and scope.

The flowchart shown in Fig. 4 describes the process that a teacher must follow to create a new TBO instance along with its minigames. The process begins by entering the initial parameters: teacher identification (*TeacherId*), game target (*GTarget*), playtime limit (*PTime*) and age group (*AgeG*). In the sequence, several flows can be defined, each one corresponding to a single informatics domain (*DomInf*). Each created flow should contain at least one minigame, chosen with a specific CT skill and level of difficulty (*LDiff*). The procedure enables the creation of multiple minigames flows (Fig. 3) establishing the framework for the overall game structure. Considering the player's perspective, when a flow begins, the initial minigame blocks the next one in the sequence, and so on successively, defining an order that must be followed in the flow gameplay.

Other possibility is conceived for TBO instance creation and the sequence of minigames definition. This includes the option of randomly defining flows based on choices among parameters associated with the minigames, namely age group, playtime and CT skills.

3.1 Prototype Implementation

The initial TBO prototype was proposed with the composition of 10 minigames from different computer science domains and CT skills, based on Bebras tasks tailored for seventh and eighth grades (cadet category). The Unity game engine [29] was chosen for the development of the EER game-like, in which the main scenario is a temperate forest environment, where the beaver must escape from.

The prototype was designed to execute on both mobile devices and desktop computers, with the potential for expansion to virtual reality headsets. Figure 5 shows a TBO minigame screenshot, named "Hamburger recipe", in which four sandwiches are prepared with ingredients associated with letters. The player must assemble a new sandwich, according to three specific letters, using the four initial sandwiches to discover the respective ingredients. The informatics domain is DSR, as set theory (intersection and difference) is used to identify ingredients and the pattern recognition is the required CT skill.

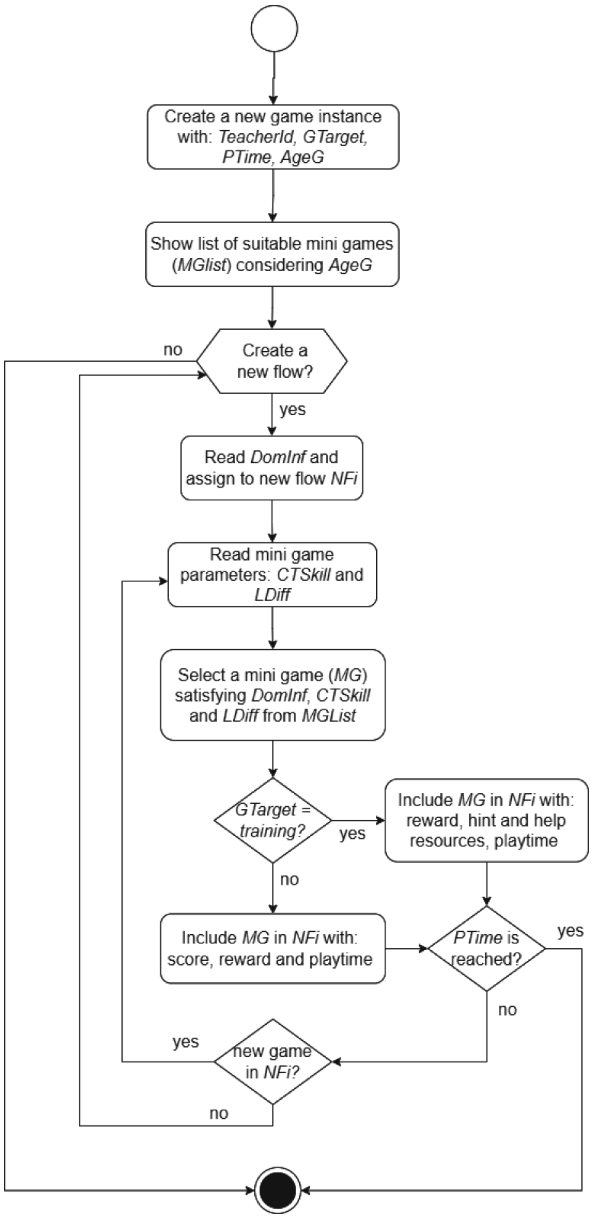

Fig. 4. Flowchart for TBO instance creation.

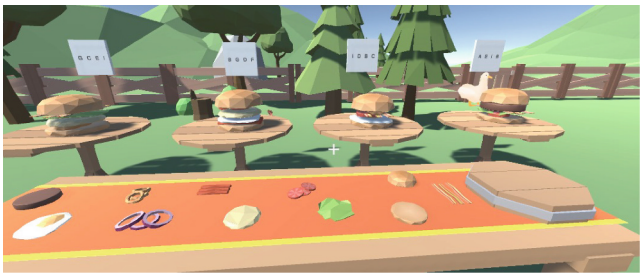

Fig. 5. Screenshot from TBO: Hamburger recipe minigame.

4 Conclusion

In conclusion, this paper presents a customizable virtual reality escape game-like designed to promote CT learning and evaluation in basic education. Leveraging escape room concepts and incorporating a series of minigames inspired by Bebras challenges, the project engages in computer science themes. The strategic design of categorical flows ensures that specific informatics domains and CT skills are effectively trained and evaluated. Considering that each minigame is intricately associated with informatics domains, CT skills, difficulty levels, and age groups, the escape game offers a highly customizable learning environment. Developed using the Unity 3D framework, the project is poised for further advancement through testing, case studies in traditional classrooms, and comprehensive assessment of outcomes from both students and teachers. At the current stage of the project, a set of minigames are being developed to address the domains described in Table II. After the development of the minigames, an environment will be developed to promote their integration following the proposed narrative. This initiative represents a significant step forward in promoting CT education through innovative and immersive pedagogical approaches.

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Development of an Augmented Reality Guide for a LASER Cutting Machine

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Abstract. This article presents the development of an Augmented Reality (AR) application designed to serve as a practical guide for operating a LASER cutting machine in a prototyping laboratory. Recognizing the limitations of traditional guides, such as manuals and video, the application utilizes AR technology to provide an immersive and interactive learning experience. The system projects virtual 3D objects onto the machine, offering step-by-step instructions for safe and efficient operation. The developed platform allows users to customize their work easily, allowing the addition of new markers, 3D models, and modifications to the instruction sequence. A usability evaluation was conducted with students and staff, demonstrating overall satisfaction with the application.

Keywords: Augmented Reality · LASER cutting · guide

1 Introduction

A prototyping laboratory serves as a dynamic space for the exploration and realization of ideas, projects, and prototypes, equipped with a diverse array of tools and machinery, ranging from basic implements such as rulers to sophisticated 3D printers. Although simpler tools may be utilized independently, more advanced equipment, such as a LASER cutting machine, typically necessitates guided usage and the presence of an on-site technician.

Efficiency in these laboratories could benefit significantly from a practical guide that supports independent use. However, traditional paper or video guides fall short in capturing the intricate reality of machine operation.

Text-based manuals are difficult to use when operating equipment and can be inaccurate, while videos often do not allow for the interaction necessary to fully understand how equipment works. In this context, augmented reality (AR) emerges as a way to overcome these restrictions and boost learning, as it allows interactivity and can include both the completeness of printed manuals and the ease of use of a video, but with interactivity.

Emerged in the 1990s, Augmented Reality requires the combination of real and virtual objects in a real environment, real-time interactive manipulation

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of virtual objects and three-dimensional alignment of virtual objects or user immersion [1]. AR's ability to present both abstract concepts and 3D spatial information makes it an excellent tool for training in situations that require manipulation of objects in the physical world [12], such as in situations involving the operation of heavy machinery, where the Precise handling is critical but difficult to learn without direct supervision.

In the context of a prototyping laboratory, a manual based on Augmented Reality can play an important role in capturing the user's attention and promoting self-guided learning, overcoming the problems of traditional guides.

Examples of this can already be seen in equipment maintenance and operator training, as shown in the work of Pilati [9] and Bosh [2].

Furthermore, Lorenz et al. [6] highlights that Augmented Reality, by facilitating quick access to documentation, facilitating guided orientation through projections of 3D objects, allowing the interaction of experienced users via telepresence and providing the freedom to use both hands, has as a One of its great advantages in the areas of industrial assembly and maintenance is the promotion of safety.

This article describes the design and development of an AR application tailored to specific requirements in a prototyping laboratory. The main objective of the project was to create an electronic user guide that supports the operation of a LASER cutting machine using AR technology.

This application facilitates user interaction with the cutting machine by presenting, on a cell phone screen, 3D images superimposed on the real image of the machine, providing guidance for efficient and safe operation.

The 3D images presented over the image from the cell phone camera provide step-by-step instructions for operating the machine safely and efficiently. The application built aligns with the "do it yourself" idea of FabLabs, promoting user autonomy, in addition to reducing the demand for assistance from laboratory technicians.

This article is organized as follows. Section 2 presents concepts about AR. The industrial application and use of AR is presented. Section 3 covers related work that used AR for maintenance and training. Section 4 details the application developed, and the technology involved. The conclusion and future work are defined in Sect. 5.

2 Theoretical Basis

Augmented Reality, as defined by Azuma [1], requires three characteristics: combining real and virtual objects in a real environment, enabling the user to visualize virtual objects in this environment using a camera; being interactive in real time, allowing the user to manipulate virtual objects in some way; the virtual object being aligned in three dimensions, enabling user immersion with the object.

Technology facilitates the process in the field of equipment maintenance and professional training. The ability to combine abstract concepts and 3D spatial

information in the context of real objects makes AR an ideal tool for training in situations that require object manipulation [12]. The use of heavy machinery requires careful handling, which is challenging to learn without a supervisor or guide nearby. A text manual can be difficult or time consuming to interpret, and it only contains static diagrams. A step-by-step video provides visual instruction but requires the user to constantly switch between the video and the application. AR offers real-time and interactive training, where instructions in the context of real objects are presented directly in the user's field of view. For example, a text prompt may indicate which tool should be used now, an animation demonstrating where to fit a particular piece, which lever to pull, etc. AR for training and maintenance has even been used in the industrial context, as seen by Bosch et al. [2].

Among the requirements for assembly and maintenance in the industry, safety is the most important. Dealing with heavy and dangerous machinery and tools is common in the field. The user should always follow the recommendations of their superiors and be able to seek help if necessary. In the context of Augmented Reality in the industry, Lorenz et al. [6] highlight several points, including the user having quick access to any necessary documentation; obtaining guided orientation with the projection of 3D objects; having access to assistance from a more experienced user with whom they can interact (in-person or through telepresence); and possibly of greater importance, the free use of both hands.

3 Related Work

Augmented Reality (AR) has been used for training in industry for some time. Yuan et al. [13], for example, introduced the Virtual Interactive Panel (VirIP) that allows interacting with AR systems, providing a guide for assembling products. The application uses virtual buttons with assembly information activated by an interactive pen. The pen enables AR interaction without placing markers or tracking objects. The software also incorporates a hierarchical tree structure that makes it easier to manage and retrieve information and instructions in an AR environment.

Westerfield et al. [12] also addressed the challenge of widespread Augmented Reality (AR) training. Using the idea of Intelligent Tutor Systems (ITS), the project was validated as the creation of the Motherboard Assembly Tutor (MAT), focused on assembling computer motherboards.

Bosh et al. [2], in turn, developed a practical guidance model that uses projectors to superimpose virtual objects on the user's surroundings. In five industrial test cases, the study demonstrated the efficiency of the learning process for new employees in assembly plants. Although these employees still spent more time than the already trained employees, the learning was considered quite satisfactory by the domain experts.

Pilati et al. [9] used Augmented Reality (AR) in conjunction with motion capture (MOCAP) for an assembly manual. The system tracks the user's movements, especially those of the hands, providing real-time feedback during assembly. The parts and tools used in assembly are placed on a worktable and a camera

films these elements. Using computer vision algorithms, alerts are displayed on a monitor if the operator selects the incorrect element. Studies of learning in test and real factory environments have revealed a reduction in time spent during the initial learning cycles.

Also employing computer vision, Mobile Augmented Reality Maintenance Assistant (MARMA) is an application developed by Konstantinidis et al. [?] o help with quick maintenance tasks in Industry 4.0. The system connects to a factory's database that stores the characteristics and 3D models of all important parts in its inventory. Using a mobile device's camera and computer vision algorithms, the application compares the part viewed on the camera with the data in memory. When it finds the correct match, it loads the CAD model of the relevant part onto the mobile device screen, along with all the necessary information and relevant step-by-step maintenance instructions. The operator views everything on their mobile device and interacts with the guide through a predefined on-screen interface.

In the field of remote assistance, Obermair et al. [8] compared Augmented Reality (AR) compared its potential with paper assembly instructions. In this scenario, a machine operator uses an AR application on a mobile device, while the second provides instructions, placing 3D objects and text messages in a virtual space. Despite possible tracking errors, the study showed greater efficiency than text guides. However, problems such as sudden movements and network outages have shown loss of synchronization and the need for the first operator to hold and release the device during communication results in lost time.

Sebillo et al. [10] address the challenges encountered by emergency teams in rescue zones using mobile guidance systems, especially when users are unfamiliar with the technology. Through an AR mobile application, the system guides professionals in real-time simulations of the consequences of their decisions, promoting familiarity with the technology and involving them in the decision-making process. The application offers essential information, such as the number of victims and risk points, improving professionals' perception of the current situation, through real-time feedback.

Unlike alternatives requiring constant operator support, Chen et al. [3] developed a hands-free assembly training system for the industry, named Projective Augmented Reality System (PBARS). Using a projector and viewpoint tracking, PBARS dynamically projects images based on the user's viewpoint, enhancing immersion. However, portability is compromised. The system incorporates predictive image analysis algorithms for part recognition and assembly monitoring.

The development of an Augmented Reality (AR) guide application for operating a LASER cutting machine has been previously addressed by Imanipour et al. [5] at the Université de Lorraine. Their implementation uses markers around the machine for tracking, employing Microsoft HoloLens 2 (mixed reality headset) for a hands-free and immersive experience. In their efforts to generalize the system, Imanipour et al. introduced a script editor that enables the definition and modification of each individual step in the guide. This application is considered an example of what we aim for in the final state of our application. Their

method of projecting information boxes with instructions, for instance, served as inspiration for the structure of our tutorial.

To summarize what has been presented in this section, Table 1 allows for a comparison of the main aspects of the related works. By analyzing this table, it is possible to deduce the popularity of the mobile platform in AR applications and the high frequency with which it is applied to technician training. Even considering its limitations, its accessibility due to its low cost and portability should not be ignored. A mobile device allows greater user flexibility with the application and is accessible. However, the techniques used are quite varied.

Table 1. Summary of related work. (Purpose A: Assembly; T: Training; R: Rescue)

Author	Utilized technique	Platform	Purpose
Yuan, 2008	Markerless, VATS	Mobile	A
Westerfield, 2015	ITS, Markers	Mobile	A/T
Bosch, 2020	sAR	Projected	A/T
Pilati, 2020	MOCAP	Fixed camera	A/T
Sebillo, 2016	Feedback real-time	Mobile	T/R
Obermair, 2020	Remote Assistance	Mobile	T
Konstantinidis, 2020	MARMA	Mobile	T
Chen, 2020	PBARS	Projected	A/T
Imanipour, 2023	Markers	Mobile	T

4 Developed Project

This section presents the LASER cutting machine and how it should be operated; the application developed throughout the project and details about its components and operation; finally, an overview of the algorithm and tracking technique employed by the application. A demonstration video can be seen at http://tiny.cc/DemoVideo_AR_LASER_CUT.

4.1 Target Machine

This project focuses on the CMA1008-B-A model LASER cutting machine Fig. 1, capable of cutting various materials such as MDF, acrylic, and paraffin paper. The software used for pre-configuration is SmartCarve 3. Detailed knowledge of the program is outside the project's scope and is managed by the laboratory technician. The developed application mainly addresses the manual operation of the machine with minimal interaction with the software.

Key machine elements: cutting compartment cover, nozzle, embedded interface, and cooling buttons. Activate components before use to ensure proper

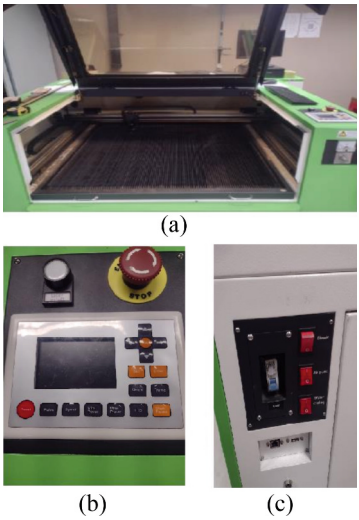

Fig. 1. Machine interior (a), interface (b), cooling system buttons (c).

functioning and prevent damage. Calibrate the nozzle for the specific material. The interface monitors cutting time, nozzle movement, and emergency stops.

The optimal operation of the machine can be summarized in the following step-by-step process:

1. Make sure that all cooling components are turned on and that the LASER activating button is off.
2. Open the cutting compartment and insert the material to be cut.
3. Calibrate the cutting nozzle over the material, using the machine interface if necessary.
4. Adjust the cutting nozzle above the desired cutting origin point and define the cutting origin point on the interface, pressing its button.
5. Close the cutting compartment and press the LASER activating button.
6. Click Start on the SmartCarve 3 software.
7. Wait for the cut to finish.
8. After the cut is finished, disable the LASER button and open the cutting compartment.
9. Remove the cut material, close the compartment, and turn off the cooling components.

4.2 Application Features

The developed system enables the configuration of any ordered sequence of instructions in an Augmented Reality (AR) environment, utilizing pre-defined

3D models and markers (images). Its execution relies on three fundamental components: 3D models, markers, and an order specified in a text file. The order dictates the sequence of instructions, and when the system tracks and recognizes a marker, it projects the corresponding 3D model onto it in the virtual scenario.

The implementation is sufficiently generalized, allowing any developer with basic knowledge of Unity (the utilized development platform) to easily modify and add their own markers and models. This can be achieved with minimal effort, leveraging the platform's features, and adjusting the combination of these elements by simply editing a configuration file. Additionally, the order can be dynamically changed in real-time through an online form interface. Before generating the executable, new images and 3D models can be inserted into the application using the same or a more recent Unity version. Through these modifications, the application can be adapted for various specific cases, such as providing a guide for a different LASER cutting machine or a 3D printer. This adaptability is crucial for accommodating different assets, such as unique 3D models, since the current project version for the prototyping lab test includes only assets relevant to the specific case at hand.

The entire application can be divided into three parts: Introduction, Configuration and Guide. The Introduction screen shows some basic information to the user, such as operation mode and markers to follow. For our test case, there are 3 makers as shown on the left-hand side of Fig. 2. When clicking the 'NEXT' button, the system progresses to Configuration.

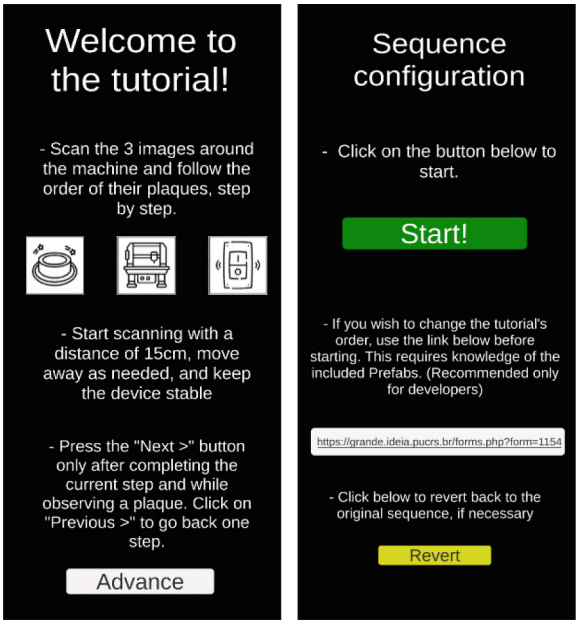

Fig. 2. Initial Screens.

The Configuration screen facilitates the definition of the instruction sequence (Fig. 2—right). A central button on the screen links to an online page where users can define combinations of steps, markers, and models, provided that these are already in the application. The page outlines the correct format for instruction orders, with a field for sequence input. Each line in the order represents a new step, containing details such as the names of the "target" marker, the model to be projected over it, and an "error" model. Once the correct order is defined, the website's database records it in a table read by the mobile application. When the user clicks the START button, the application goes into Guide mode, in which the sequence of instructions is executed. The device camera is activated, initiating image tracking. In the case of our project, the markers used were placed around the LASER cutting machine, as in Fig. 3. We used only three markers to maintain simplicity and because they were found sufficient to draw the user's attention to the machine's 3 most important places (Fig. 4).

Fig. 3. Markers installed over the machine.

To help the user to know in which step he is, at the top of the screen (Fig. 4) there is a counter, and the Previous and Next buttons that allow the user to freely move between instructions.

When a known marker is identified by the camera, the application 'looks' at the current line in the sequence. If the marker is the same as the defined 'target' image, the system virtually projects the corresponding 3D model over the tracked marker. Otherwise, the 'error' of the models is projected. This model is projected over all the markers that are not the target for the current step. At the end of the tutorial, the user can restart the process or finish the application.

When a known marker is identified by the camera, the application 'looks' at the current line in the sequence. If the marker is the same as the defined

(a) (b)

Fig. 4. Interface elements: (a) Target plaque; (b) "incorrect" plaque.

'target' image, the system virtually projects the corresponding 3D model over the tracked marker. Otherwise, the 'error' of the models is projected. This model is projected over all the markers that are not the target for the current step. At the end of the tutorial, the user can restart the process or finish the application.

The application was developed for mobile systems because of their accessibility and portability. With the ability to obtain the application on a smartphone, any student who has such a device can use it. The current executable is made for Android systems, and was used on a Motorola G9 model cellphone, since it is what we had available. We are considering an executable for iOS systems in the future. We utilized the Unity development platform, a free and popular game engine; we chose it because of our familiarity with the platform and its flexibility to develop interactive systems. Unity facilitates the implementation process since it possesses AR Foundation [11], a library dedicated to racking, projections, and general implementation of AR and VR applications. The current executable can be loaded and installed on any Android system compatible with the latest version of Google ARCore using the publicly available project at GitHub (URL Omitted).

5 Technologies Used

The AR Foundation offers the essential environment and tools for object detection in our physical surroundings, enabling the creation of a virtual scenario where various virtual elements can be projected onto the real environment. This project specifically employs image-based tracking using markers. The platform defines the images to be tracked within an internal reference library. The AR Foundation enables Unity to utilize the internal tracking capabilities of the hardware, such as Google ARCore [4], which employs odometric and computer vision methods to identify these images in the environment.

6 Usability Evaluation

At the end of the project implementation, a usability evaluation of the developed application was conducted. The elements evaluated were based on the questions used by Imanipour et al. in their research, as they adequately represent the test users' opinions on the method used. Like the NASA TLX evaluation method [7], this assessment asks subjective questions of the test group and then organizes the collected data objectively. The survey asked users the following questions:

1. How useful is the application for learning to use the machine?
2. How capable do you feel of performing a LASER cut on your own?
3. How clear is the learning process followed?
4. During training, how often did you feel the need for an explanation from a tutor?
5. How easy is the application to use?
6. How clear and well-structured is the application interface?

Each question is assessed on a scale of 1 to 5, representing different levels of quality. A response of 1 indicates "very bad," 2 corresponds to "bad," 3 is "neutral," 4 signifies "good," and 5 represents "very good." These responses gauge the user's satisfaction with the application for each specific question. However, Question 4 follows a different approach, where a score of 1 reflects "very high frequency," 2 indicates "high frequency," 3 is "neutral," 4 suggests "low frequency," and 5 denotes "no frequency." The final data were then compared to determine the most frequently chosen response for each question, shedding light on any challenges encountered by users with the application.

The data evaluation aimed to identify improvements to enhance the accessibility of the application to prototyping lab users, assess the number of users who completed the step-by-step without problems, and determine overall user satisfaction. Before conducting the evaluation with the target audience, the application was tested by two technicians experienced in machine operation, who provided valuable suggestions that were implemented. The evaluation, approved by the Internal Review Board, included a total of 17 users. Among them were eight Architecture and Urbanism students, four Design and Communication students, four administrative staff, and one lab technician, all possessing basic knowledge

of the machine. The remaining users had no prior experience with the machine. Among the 17 users, 4 were in the 40–50 age group, while the rest (all undergrad students) were in the 20–30 age group. All users were familiar with smartphones, but only 4 had previously used an Augmented Reality application. Each test was carried out with the machine already on, considering its frequent daily usage. Nonstudent users received a standard cut of a cell phone holder. The results of the user questionnaire are depicted in the accompanying graphs. Figure 5 illustrates the responses to Questions 1, 2, 3, 5, and 6, while, Fig. 6 provides insights into Question 4.

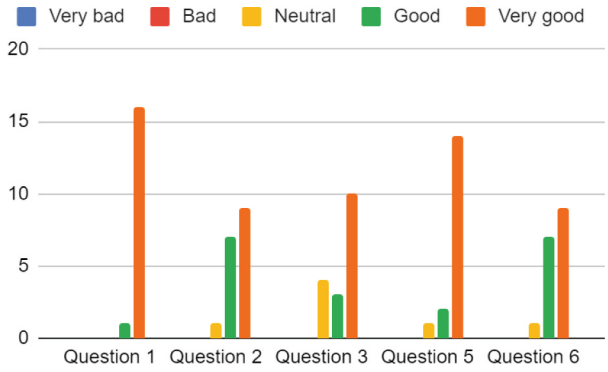

Fig. 5. User evaluation on questions 1, 2, 3, 5 and 6.

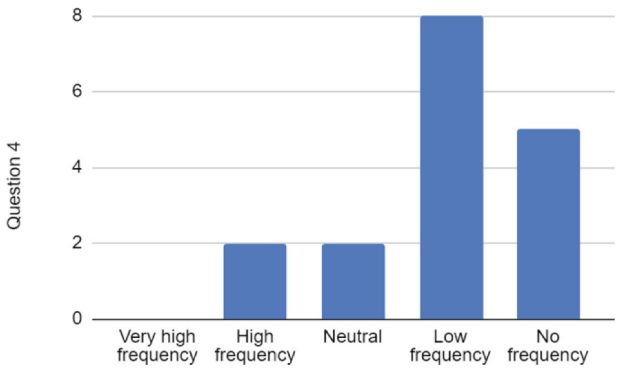

Fig. 6. User evaluation on question 4.

All participants successfully navigated through the step-by-step instructions, completing the intended cut. The average execution time for the guide (excluding

cutting time) ranged between 10 and 15 min. However, older users took approximately 20 min, indicating an increased difficulty with the application. Upon reviewing Fig. 5, a notable prevalence of scores 4 and 5 is observed throughout the questionnaire, particularly in questions 1 and 5.

This indicates that most users found the application helpful for learning machine operation and user-friendly. Many users expressed confidence in independently performing a cut after training, though some mentioned feeling more secure if they could use the guide again. Despite Question 4 receiving predominantly positive responses, six out of 17 users encountered difficulties interacting with the machine interface, necessitating the author's intervention and guidance in certain steps. In particular, Design and Communication students voiced concerns about the lack of an indicator showing the preceding and subsequent steps.

7 Conclusion and Future Work

The exploration and implementation of Augmented Reality facilitated the creation of a guide for operating a LASER cutting machine. We established a theoretical foundation for the technology, recognizing its widespread use in industry for maintenance and training, leading to the definition of our platform. The developed system enables flexible configuration of ordered instruction sequences in an AR application, allowing users to seamlessly modify steps, markers, and models, even adding new elements without conflicts. A usability evaluation involving students and university staff showed that most found the application satisfactory and easy to use. The executable is publicly accessible online, enabling any FabLab student with a compatible device to independently install the guide and operate the LASER cutting machine with minimal assistance from a lab technician.

Future considerations include implementing a real-time step order viewer and developing an iOS version to enhance accessibility for the broader prototyping lab audience. There is a particular emphasis on creating a mechanism that allows the modification of 3D models and markers post-compilation or even in real time. This focus aims to make the application more dynamic, fostering accessibility for developers, and expanding its applicability to diverse scenarios.

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Financial, Tax and Accounting Literacy - a Study in the 12th year of Secondary Education

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Abstract. This paper aims to study the level of financial, tax, and accounting literacy among 12th graders. This work is divided into two main groups: the first focuses on the literature review and the second on the empirical study. In order to reach the conclusions, a questionnaire was used as a data collection tool, implemented with students from two secondary schools in the city of Aveiro, Portugal. The conclusions drawn are in line with what was expected and what has already been concluded in other studies, i.e., the level of financial, tax, and accounting literacy is classified as medium-low. This study is relevant because it shows how necessary it is to focus on these issues in order to prepare young people for the needs of the present and the future.

Keywords: Financial Literacy · Tax Literacy · Accounting Literacy · High School

1 Introduction

Internationally, there is an increased concern to improve the level of financial literacy of citizens, since more financially literate individuals make decisions in this area in a more conscious, informed, thoughtful, and assertive way, reducing the risk of making harmful decisions. In fact, financial decisions are one of the factors that affect people's quality of life ([1–3]).

This concern also exists in Portugal, as it is increasingly clear that the level of financial literacy of the Portuguese is far from being well-positioned, as revealed by the results of surveys carried out by the Bank of Portugal (BP)[1]. To this end, a number of programs have been carried out to enrich citizens' financial literacy, through initiatives by the BP[2], other banking institutions, and even the Organization for Economic Cooperation and Development (OECD).

[1] For further details, please see: https://www.bportugal.pt/

[2] BP has promoted a number of initiatives to promote financial literacy, such as the Banking Customer Portal and the Population Financial Literacy Surveys.

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In Portugal, studies have been carried out in order to understand the financial motivations of citizens, as well as to quantify the level of literacy of the Portuguese. However, these studies focus a lot on investments, savings, loans, family budgets, and inflation, as is the case internationally ([4]).

Given the complexity of the daily operations to which an individual is subject, it is increasingly clear that there is an imperative need to rapidly improve what is known as 'financial literacy' ([5]); which is why it is our understanding that financial literacy encompasses, in addition to the financial perspective, the fiscal and accounting perspectives.

The main objective of this study is to measure the level of financial, accounting, and tax literacy of students in the 12th year of secondary education at two secondary schools in the city of Aveiro, as well as to understand what factors may influence this level of literacy. Through the dissemination of a questionnaire by the students, the aim is to answer the following research questions: what is the level of financial, fiscal, and accounting literacy of young people in the 12th year of secondary school; what factors can influence this level?

2 Literature Review

2.1 Financial Education

In general, the population has low levels of financial literacy ([6–8]) and so there is a problem of financial literacy, which is worrying for policymakers, professionals and researchers, given the complexity of transactions today ([5, 9, 10]). However, financial education is easily confused with financial literacy, and it is therefore important to differentiate between them. Thus, financial education is the process through which citizens develop knowledge about financial concepts and content, becoming more alert to risky situations, thus improving their financial well-being and contributing to a more economically healthy society; Financial literacy, in turn, aims to stimulate the attitudes and behaviors, through this knowledge, that lead to informed and responsible decision-making in a financial context ([4, 11–13]). So, the lower the level of financial education, the lower the degree of financial literacy and, consequently, we see a reduction in social welfare and economic development through unproductive investment decisions [14].

Once we are aware of the lack of financial knowledge, it is crucial to understand where individuals can obtain this knowledge, as it will be different for each age group [15].

Now, if we're talking about younger individuals, they can acquire this vital skill through educational programs and finance subjects in schools ([2, 6, 7, 16–21]), or through augmented reality with younger children in early childhood ([5, 22, 23]), or through financial training ([24]) and with banking institutions through financial advice ([25, 26]), or even working with government institutions ([1]).

However, older people don't have as many opportunities as young people to obtain this knowledge, for example, through classes; then senior citizens' associations or adult education centers take on the role of information sources [3].

Various initiatives have been taken worldwide to promote financial knowledge, for example, through banks ([8, 20]), or through the creation of websites to promote and

disseminate financial literacy ([5, 9]). The OECD has also been working on this issue, carrying out a number of studies in this regard, most notably PISA (Programme for International Student Assessment), which is a worldwide study of OECD member and non-member states, aimed at assessing young people's ability to use their knowledge and skills to face real-life challenges, rather than just mastering specific curricular content, particularly in areas such as mathematics, science and reading ([27]). Thus, PISA 2012 was the first large-scale international study to assess the financial literacy of young people. It concluded that there is a strong link between knowledge and financial literacy ([28]) and that policies to promote financial literacy should reach all students, especially those from lower socio-economic backgrounds ([27]). Subsequently, PISA 2015 ([29]) and PISA 2022[3] were launched.

In Portugal, after the 2008 crisis, financial literacy began to be given more importance, with more studies starting to appear in this direction and various organizations promoting financial literacy actions. Therefore, governments and educational institutions need to be concerned with preparing financial literacy programs, since it is part of the school's responsibility to train students in a variety of areas, right from the early years of schooling ([13, 30]). However, despite widespread support for educational measures to increase savings from early childhood, there is still no complete understanding of why and how people save ([31]). The emergence of the REF (Financial Education Framework), drawn up by the Ministry of Education in partnership with the National Council for Financial Supervision (CNSF), has helped teachers at different levels of education ([13]), from pre-school to adult training courses. Based on the REF, the CNSF created a more comprehensive document, the PNFF (National Plan for Financial Education), in 2011, with well-defined objectives to combat financial illiteracy among young people and even entrepreneurs. Later, the PNFF (2016–2020) came out with a new feature in relation to the first: the attention given to digital means of access to financial services, with the creation of the Everyone Counts' portal ([32]). Currently, in Portugal, the PNFF (2021–2025) is in force and is based on the same principles as the previous ones, with the difference of the existence of a pandemic period, which brings new challenges due to the risks that families are subject to.

In addition to all these initiatives, the BOP also designed the 'National Survey on the Financial Literacy of the Population', carried out for the first time in 2010; subsequently, the second and third surveys were carried out ([32–34]). In both surveys, some asymmetries were detected in the level of financial literacy of those surveyed: for example, individuals with lower incomes and lower levels of education tended to show a greater lack of knowledge ([35]).

2.2 Financial Literacy

Financial literacy is not uniquely and universally defined [26], although it is understood as a social skill, essential for living and thriving in the modern economy, affecting economic and financial stability individually and collectively [1, 30, 36]. However, it is an ability to process economic information and make effective decisions about wealth

[3] For further detail, please see: https://www.oecd.org/publication/pisa-2022-results/

accumulation and financial planning [37], which requires a minimum knowledge of financial terms such as money, inflation, interest rates, credit and others [25].

The notion of financial literacy is not only confined to economics, but also includes management, psychology, pedagogy and other branches of science ([18, 38]), as this concept covers a wide range of economic and financial actions, behaviors and decisions, including effective money management strategies [39]. Financial literacy therefore means having the knowledge and understanding of financial concepts and risks, and the skills, motivation and confidence to apply this knowledge and understanding in order to make effective decisions in financial contexts, with the aim of improving the financial well-being of individuals and society ([4, 8, 16, 18, 40–43]). Financial literacy is fundamental, as better-informed citizens make decisions about choosing the right financial products, helping to monitor the markets and thus contributing to greater stability in the financial system [33].

In order to examine financial literacy in an individual, it is very important to take into account these three factors: financial knowledge, financial behavior and financial attitude [8]. Thus, financial literacy increases financial planning and this, in turn, possibly improves financial behavior ([11, 20, 44]).

However, having good levels of financial literacy is not only beneficial on a personal level, but it is also very important on a professional and business level, especially with regard to entrepreneurship ([18, 42, 43, 45]).

According to some studies, there are many factors that affect an individual's level of financial literacy ([41]). The variables 'attitude' and 'financial behavior' influence individuals' level of financial literacy ([4, 7, 8, 14, 20, 38]); there is also a linear link between financial knowledge and financial behavior ([4, 8]); gender has an influence on an individual's level of financial literacy [14], such as men being more financially literate than women ([4, 6, 14, 15, 19, 30, 46]); there are also studies to the contrary, i.e. that there is no linear relationship between gender and the level of financial literacy ([2, 23, 47, 48]). However, there is a statistically proven relationship between the 'age' factor and the level of financial knowledge ([4, 7, 14, 30, 38]). The literature also confirms that the level of income affects the level of financial literacy ([4, 6, 14, 15, 19, 26, 38, 49]), as well as the level of household debt and the household budget ([7, 23, 50]). Marital status ([7]) geographical region and household ([7, 15, 19, 20, 38]), as well as educational background and prior knowledge ([10, 19, 21, 23, 30, 47]), are also shown to influence an individual's level of financial literacy.

When it comes to measuring and assessing the level of financial literacy, there is a lack of standardization, as various authors have demonstrated different methods for measuring the level of financial literacy ([18]); however, ([6, 8, 14]), used the same method, questionnaires, structured on Likert scales.

According to [51], there are significant differences in the level of financial literacy between countries. Thus, through the studies analyzed ([8, 21, 41–43, 52–54]), India, China, Tunisia, Ghana and the United States of America have low levels of financial literacy. Indonesia, Romania, Brazil, Mexico, and the United Kingdom are at an intermediate level of financial knowledge ([22, 38, 49, 51]). With the highest levels of financial literacy, Turkey, Germany, and the Czech Republic stand out ([2, 3, 10, 26]).

In Portugal, the level of financial literacy is considered low, as there are still many difficulties in understanding basic financial concepts ([24, 33, 50]), and this is especially true of older people and those with more financial difficulties, as well as students and the unemployed. Portuguese families are increasingly in debt ([55]); however, a small percentage of the population still thinks about the future and saving ([23]). Although the results are clear and show an improvement in the financial behavior and attitudes of the Portuguese ([32, 34]), there is still a lot of work to be done in terms of financial knowledge, since Portugal also comes in seventh place in the global indicator of financial literacy [56].

3 Methodology

This empirical study used a questionnaire, which is an instrument for collecting data on objective questions and is one of the most widely used data collection techniques in the social sciences [57].

The questionnaire is divided into five groups of questions: group I, to identify the respondent; group II, with questions on financial literacy; group III, with questions on tax literacy; group IV, with questions on accounting literacy; and group V, with questions on awareness. This data collection instrument is anonymous, voluntary, and its data protection is guaranteed. Before it was implemented in the schools, it was subjected to a pre-test, which was also carried out with 12th-grade students from a school other than those mentioned in the study. In total, 456 students from the two schools under study were enrolled in the 12th grade, and our sample consists of 73 valid responses.

The main objective of this empirical study is to measure the level of financial, tax and accounting literacy of 12th graders, as well as to understand the factors that can influence this level of literacy, thus answering our two research questions: 'what is the level of financial, tax and accounting literacy of young people in the 12th year of secondary school?' and 'what factors can influence financial, tax and accounting literacy?'.

To answer the first research question, the level of financial literacy was obtained from the overall average of the correct answers, following ([21, 23, 46, 48, 49]). This level was then calculated by questionnaire group, i.e., by type of literacy. It should be noted that the percentage of correct answers was taken into account when classifying the level of financial, tax and accounting literacy: below 50% means that there is a low level of literacy; equal to or greater than 50% and up to 70% means that the level of literacy is average; from 70% upwards we consider a high level of financial, tax and accounting literacy, in accordance with the method used by [48].

Given the literature, it is expected that literacy levels in this study will also be low. However, we also want to understand which factors influence literacy levels, thus answering the second question posed, and we have therefore formulated the following hypotheses (Table 1):

To test the hypotheses, the data were processed in SPSS V27, and the answers were recoded as dummy variables. Finally, we used the Student's t-test to answer the last research question.

Table 1. Study Hypothesis.

Hypothesis	Description
(1): (Gender)	Female students have a lower level of financial, tax, and accounting literacy than male students
(2): (Previous training)	Students who have received previous training in finance demonstrate a higher level of financial literacy
(3): (School)	School influences the student's level of financial, tax, and accounting literacy
(4): (Course)	Students on a course closer to the financial area have a higher level of financial, tax, and accounting literacy

4 Results and Conclusions

Our sample consists of 73 valid responses, 48 of which are from the Dr. Mário Sacramento Secondary School and 25 from the José Estêvão Secondary School. The majority of respondents are female, accounting for 62% of responses, while 35% of respondents are male. Regarding the area of study attended, the majority of students are enrolled in regular education courses, with the Languages and Humanities course standing out with 54.79% of the responses. The table below shows the results of the overall level of literacy (Table 2).

Table 2. Financial, Tax, and Accounting Literacy Level.

Total number of answers	Correct Answers
1752	879
Average:	**50,17%**

Once the overall literacy level had been determined, we checked the level for each type of literacy. Thus, in the group of questions on financial literacy, the students obtained a level of financial literacy of 52.97%, i.e. a level considered to be medium to low, as mentioned by [48]. Other researchers ([58, 59]), have also reached a level of financial literacy very similar to this in their studies of secondary school students. These results are in line with the findings of the OECD [56], where Portugal ranks poorly compared to other countries. As a result, it was concluded that the level of financial literacy of the Portuguese is still far below what is desired and needs to be improved, as can also be seen in the results of the latest Portuguese Financial Literacy Survey, carried out by the Bank of Portugal [34]. In general, students found it more difficult to distinguish between the various types of investment possible and which are the most profitable.

Regarding the level of tax literacy, young people achieve an average level of tax literacy (55.34%), since according to [48], it is considered average when it is between 50% and 70%. Like [60], the majority of respondents were not tax literate, which is

why the author states that it is important for people to be concerned with acquiring tax knowledge, as this will lead to greater justice, less inequality, and greater growth, since those who show the least knowledge are the youngest. In our study, the majority of respondents have a good understanding of the purpose of taxes and their meaning, as well as the VAT rates in force, but they don't check their invoices or fill in their own personal tax return, which is filled in by an accountant.

Of all the groups in the questionnaire, the lowest results were presented in the accounting literacy group (42.74%), i.e., a low level of accounting literacy. The majority of respondents know about the profession of a certified accountant, but they don't know examples of financial statements or the meaning of net profit for the period. On a positive note, the respondents surprised us by demonstrating that they knew what an inventory consisted of, as well as being aware of the number of vacation days a worker is entitled to.

Finally, the level of awareness of these young people was determined, and the result was considered average at 60.73%. The vast majority of respondents (86.30%) had never taken part in a financial training initiative. With regard to consumer behavior, the majority showed that they adopt the most appropriate attitudes and behaviors in relation to consumerism.

To answer the second research question, we carried out a Student's t-test, based on the result obtained through the overall literacy level (overall average of correct answers per respondent) with our sociodemographic variables under study: SEX; FINANCIAL TRAINING; SCHOOL, and COURSE. The following results were obtained (Table 3):

Table 3. Results *T-test*.

Financial, Tax, and Accounting Literacy Level		
	Levene test	*T-test*
Variables:	*p- value*	*p- value*
Sex	0,253	0,955
Financial training	0,195	0,212
School	0,387	0,498
Course	0,415	< 0,001

The results show that there is no statistically significant difference between the variables gender, previous financial training, and school, thus rejecting hypotheses 1, 2, and 3; these results are in line with what other authors have also found ([47, 48]). Hypothesis 4 shows a p-value of < 0.001, which shows that there is a statistically significant difference between the course variable and an individual's level of financial, tax, and accounting literacy, thus confirming hypothesis 4. In the same direction, point out ([19, 23, 30, 47]), stating that students who attend courses in socioeconomic areas have a higher level of financial literacy.

Just as other studies have presented their limitations, this is no exception, and, therefore, we expose the limitations of this study, which prevented it from achieving more

robust results, but which can be replicated for future studies. First of all, the fact that the study only focuses on 12th-year students means that it could have been interesting to cover other years of schooling and explore the number of incomplete responses. Another factor that affected our study was the fact that it was limited to a single geographical area, the city of Aveiro, and two schools in particular.

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Management Accounting in Portuguese Municipalities: Adoption and Disclosure

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Abstract. The Accounting Standardization System for Public Administrations establishes the mandatory implementation of management accounting in Portuguese municipalities, foreseeing the disclosure of the respective information in the rendering of accounts. In this context, the main objectives of this research are to study the implementation of the Public Accounting Standard (NCP) 27 in Portuguese municipalities, with regard to the adoption of a management accounting system and the disclosure of the respective information in the rendering of accounts. To achieve these objectives, data was collected through a questionnaire. The obtained results show that 66,3% of the surveyed municipalities have already started the process of implementing NCP 27. Regarding the disclosure of management accounting information as stipulated in points 34 and 37 of NCP 27, the majority of the surveyed municipalities only disclose costs, failing to comply with the requirement to disclose information on income and results.

Keywords: Public Administration · Management Accounting · Cost Accounting · NCP 27 · SNC-AP · Municipalities · Adoption · Reporting

1 Introduction

Management accounting has been implemented in the public sector all over the world [1]. This system plays a crucial role in supporting the internal processes of public management, as well as accountability (external aspect), as stipulated in points 3 and 5 of Public Accounting Standard (NCP) 27 - Management Accounting. In fact, the management of financial resources entrusted to the public sector implies a significantly greater responsibility than that found in the business context ([2, 3]).

This management accounting subsystem has thus emerged as an extremely useful tool for the public sector, providing managers and politicians with the ability to assess whether they are managing efficiently, effectively, and economically ([3, 4]). It is imperative for the Public Administration to control and manage the costs of the services provided in an appropriate manner, since effective management of these resources makes it possible to optimize the provision of other services ([5]).

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In Portugal, the obligation to implement a cost/management accounting system in municipalities dates back to 2002, with the entry into force of the Official Accounting Plan for Local Authorities (POCAL). However, contrary to expectations, the rate of implementation of cost accounting according to this plan has remained remarkably low [6].

One of the main reasons given for municipalities not adopting a cost/management accounting system in the past is the exclusion of the documents produced by this system from the set of information required by the Court of Auditors (TC)[1] [7]. On the other hand, one of the main reasons for its implementation is the enactment of new standards, which make the adoption of this accounting system mandatory ([6]).

With the entry into force of the Accounting Standardization System for Public Administrations (SNC-AP) and the subsequent requirement by the TC to present information from the management accounting system, it is essential to assess whether, in view of these changes, Portuguese municipalities have already adopted NCP 27 and whether they are disclosing information from that accounting subsystem in accordance with the stipulations of that standard.

Thus, driven by the importance and relevance of the topic, its recent development in Portugal, as well as the scarcity of studies in this area, the main objective of this research is to verify whether Portuguese municipalities have already implemented a management accounting subsystem in accordance with NCP 27, especially with regard to the required disclosure of information.

2 Theoretical Framework

The implementation of cost accounting as a management tool in public administration entities in Portugal dates back to 1992 [8]. Subsequently, the obligation to implement this was reinforced for local government entities with the approval of the POCAL [9].

Point 2.8.3 of the POCAL states that cost accounting "is compulsory for determining the costs of functions and the costs underlying the setting of tariffs and prices for goods and services". This determination of the costs of a good or service is carried out by aggregating the direct and indirect costs associated with that cost object.

Following on from the POCAL, the General Regime for Local Authority Fees (RGTAL) and the Local Finance Law (LFL), now known as the Financial Regime for Local Authorities and Intermunicipal Entities (RFALEI), came into force, reinforcing the obligation for local authorities to implement a cost accounting system (SCC) ([10–12]).

From 2020, with the start of the application of the SNC-AP by Municipalities, NCP 27, which is part of Annex II of that system, came into force [13].

NCP 27 is a standard aimed exclusively at management accounting, and its objective is to "establish the basis for the development of a management accounting system in public administrations" (NCP 27: 1).

By dedicating a specific standard to management accounting, the SNC-AP shows a clear commitment to improving accountability and producing information to improve the decisions of public managers ([14]).

[1] In Portuguese: Tribunal de Contas.

The management accounting systems to be developed in public administrations must take into account two types of users: internal users, in order to support internal public management processes, and external users, where the system must contribute to the purposes of accountability (NCP 27: 3, a)).

NCP 27 presents the guidelines for the development of a management accounting system (MAS), designed to produce information on costs and, where necessary, on income and results, to aid the decision-making process of public managers and directors and determines which information of this nature should be disclosed and, therefore, included in the financial statements [4].

In recent years, the decentralization of powers to local governments and their independence from central government has increased concern about transparency in local government management. This is especially relevant due to the expansion of the areas in which local government operates, such as the water, waste, sanitation, healthcare and basic education sectors, which require rigorous management of public funds ([15]).

Contrary to what happened under the POCAL, with the SNC-AP, information from the management accounting subsystem is now part of the set of accountability documents to be sent to the TC. In this way, the obligation to send information to the TC on management accounting could be a strong motivation for municipalities to develop it ([16]). However, it could lead to entities adopting management accounting just to comply with the regulations and not recognizing the importance of this system ([17]).

With regard to the disclosures provided for in NCP 27, the standard has the particularity of providing for the disclosure not only of general information, but also of specific elements to be included in the reports of the education, health and local authority subsectors, in order to obtain more detailed information, taking into account each subsector ([18]).

Thus, according to point 34 of NCP 27, in general terms, public sector entities must disclose in their management reports:

(a) "Direct and indirect costs of each good, service and activity;
(b) Income directly associated with goods, services and activities (if any);
(c) Total costs for the financial year and total accumulated costs of activities, products or services with a multiannual duration, or not coinciding with the financial year;
(c) Final cost objects for which the total cost has been determined, the overhead allocation criteria used and the costs not incorporated."

In the specific case of local authorities, information must be provided on direct and indirect costs and the respective associated income, for each good produced or service provided, for each function, unit, department or activity and also for each good or service where a price is charged or a fee levied, indicating the income and economic results (NCP 27: 37).

3 Methodology

This chapter will identify the objective of the empirical study, the research hypotheses, as well as the research methodology adopted, including the techniques and procedures used to collect and analyze the data, in addition to characterizing the sample under study.

The study aims to:

- Check the adoption of the management accounting system in the municipalities;
- Assess compliance with the disclosure of information from management accounting.

In order to achieve the objectives of this research and based on the literature review carried out on the subject, the following research hypotheses were formulated:

1. There is an association between the implementation of management accounting and the geographical location of municipalities;
2. The implementation of management accounting is related to the size of municipalities;
3. Municipalities followed the recommendations of NCP 27 in implementing the Management Accounting System;
4. Municipalities are complying with the disclosures set out in NCP 27;
5. The implementation of Management Accounting is constrained by a lack of human resources;
6. The information produced by the Management Accounting System is useful in decision making.

In order to evaluate the proposed research hypotheses and achieve the objectives of this study, it was decided to collect data using a questionnaire survey. This instrument was chosen because it was best suited to the scope of this study, its potential and the ease with which the data collected could be processed.

The decision to use the questionnaire as the data collection method was also based on existing research, since similar studies have already used this methodology (e.g., [6, 10, 19–21]).

The questionnaire was developed using the questionnaires developed by [6, 19, 21] and was prepared using the LimeSurvey computer tool provided by the University of Aveiro. This allowed respondents to answer the questionnaire directly via the link sent to their email address.

The questionnaire was made up of a combination of closed and mixed questions, with the former predominating, where the respondent chooses their answer from predetermined options ([22]). A Likert scale was also used, in which, when faced with a set of statements, each respondent indicates their level of importance or agreement according to a scale presented ([23, 24]). The questionnaire was drawn up followed by a pre-test, which allowed it to be improved.

The questionnaire was available between April 19, 2023 and May 18, 2023. By the deadline, 101 complete responses had been received from a total of 308 municipalities, corresponding to a response rate of 32.8%, which is a reasonable sample spread across the different NUTS III[2]. Given the size of the sample, it is not appropriate to generalize the results to all Portuguese municipalities.

The data was analyzed and processed using Microsoft Excel (version 2308) and the statistical tools of the Statistical Package for the Social Sciences (SPSS - version 29). SPSS was chosen because of its ability to carry out reliable statistical calculations and present its results immediately ([25, 26]).

The statistical treatment applied to the data collected was as follows: analysis of absolute and relative frequencies and *Spearman's test*.

[2] For further detail, please see: https://www.pordata.pt/en/what+are+nuts.

4 Results

4.1 Characterization of the Sample

The 101 municipalities that took part in the survey were characterized based on their geographical location and population size.

With regard to geographical location, the 101 municipalities were classified according to NUTS III. The most represented regions were the Coimbra Region (10.9%), the Área Metropolitana de Lisboa (7.9%), and the Região Autónoma dos Açores (7.9%). On the other hand, the least represented regions were Oeste (1%), Alentejo Litoral (1%), and Alto Tâmega (0%).

The size of the municipalities was analyzed based on the number of inhabitants, following the scale defined in the 'Financial Yearbook of Portuguese Municipalities' ([27]). Municipalities were grouped into three categories: small (population less than or equal to 20,000 inhabitants), medium (population greater than 20,000 and less than or equal to 100,000 inhabitants) and large (population greater than 100,000 inhabitants).

Analysis of the data shows that the group of municipalities that responded to the questionnaire with the highest representation, in population terms, is the small group, covering 55% (56 municipalities). In contrast, the large group is the least representative, with 10% (10 municipalities), while the medium-sized group represents 35% (35 municipalities).

4.2 The Adoption of Management Accounting

The aim of the questionnaire was to find out whether the municipalities had already implemented cost accounting before the SNC-AP came into force, whether that subsystem had been adapted to comply with NCP 27 and whether they had already started to adopt a Management Accounting System (SCG) in accordance with NCP 27.

Regarding the implementation of the cost accounting system before the SNC-AP came into force, 61% of the entities analyzed had already implemented it. It is important to note that, although the result obtained is still relatively low, taking into account that cost accounting became mandatory for Portuguese municipalities on January 1, 2002, with the entry into force of POCAL, it was possible to see an increase compared to various studies on the subject ([6, 7]), in which the implementation rates were 41% and 61%, respectively.

Next, we looked at whether the entities that already had a SCC, had adapted it to NCP 27, in terms of using the multiple imputation basis and implementing the ABC method. It was found that 59.7% of the 62 municipalities have already implemented the multiple imputation basis and only 38.7% apply the ABC system, a low percentage which can be explained by its complexity.

These figures suggest that a significant proportion of the municipalities surveyed have not made the full transition to the specific methods proposed by NCP 27.

With regard to the implementation of an SCG in the light of NCP 27, 66.3% of the entities surveyed have already begun this process, with the majority starting in 2020 (46.5%), coinciding with the entry into force of the SNC-AP (Table 1).

Table 1. Year of implementation of management accounting.

Year	N	%
2020	47	46,5
2021	7	6,9
2022	13	12,9
Not started yet	34	33,7
Total:	**101**	**100,0**

It is important to note that by 2022, 34 municipalities had still not started implementing this system, meaning that after two years of SNC-AP, they remain non-compliant. The situation can be justified on the basis of the provisions of IPSAS 33, which establishes a three-year transition period for the adoption of more complex accounting standards.

Comparing the adoption of management accounting, as outlined in NCP 27, with the implementation of cost accounting, in accordance with the provisions of POCAL, it is possible to see an increase in the rate of adoption of management accounting with the entry into force of the SNC-AP. This scenario possibly reinforces the influence of the obligation to send information, resulting from the SCG, to the TC, on the adoption and implementation of this type of accounting system.

4.3 Disclosure

In order to assess whether municipalities are disclosing the information provided for in points 34 and 37 of NCP 27 of the SNC-AP, questions were included in the questionnaire about their disclosure practices.

As we can see in Table 2, only 6 municipalities surveyed comply with point 34, and only 15 municipalities comply with the obligations of point 37 of NCP 27, with only 2 municipalities fully complying with the disclosures provided for in both points.

It is therefore possible to state that the vast majority of municipalities are not complying with the disclosure obligations stipulated in NCP 27. This raises concerns about the alignment of municipalities with the current accounting standard and transparency in the management of public resources. Furthermore, the small number of municipalities that have adhered to the required disclosure practices indicates that there is still a substantial way to go to reach acceptable levels of compliance.

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In this sense, it is imperative that the competent authorities reinforce guidance on compliance with the standard, promoting the adoption of best practices in accountability by municipalities.

Table 2. Disclosure of points 34 and 37 of NCP 27.

	Complies with point 34 of NCP 27		Complies with point 37 of NCP 27		Complies with points 34 and 37 of NCP 27	
	N	%	N	%	N	%
Yes	6	5,9	15	14,9	2	2,0
No	95	94,1	86	85,1	99	98,0
Total:	**101**	**100,0**	**101**	**100,0**	**101**	**100,0**

Finally, with regard to disclosure, the municipalities were asked which factors influenced it. They were asked to rate the degree of importance of those factors using a 5-point Likert scale (1 - no importance; 2 - little importance; 3 - reasonable importance; 4 - high importance; 5 - very high importance).

As can be seen in Table 3, most of the factors presented are considered important. However, two factors stand out in particular: 'Parameterization of the software used' (average: 4.35) and 'Control by the Court of Auditors' (average 3.88).

Table 3. Factors influencing the disclosure of information.

Factors (N = 101)	Average
Parameterization of the software used	**4,35**
The image of the public entity in the eyes of its stakeholders	3,24
Pressure from the external auditors responsible for issuing the Legal Certification of Accounts (CLC)	3,61
Disclose information that the Municipality considers private	**2,87**
Control by the Court of Auditors (TC)	**3,88**

4.4 Factors that Hamper the Implementation and Usefulness of Information from the SCG

The aim of this group of the questionnaire was to find out which are the main factors hampering the implementation of the SCG and for what purpose the information generated by management accounting is used.

The factors that hamper the implementation of the SCG were measured using the same scale as in the previous question. The selection of the factors presented was based on the studies carried out by [6, 20, 21].

An analysis of Table 4 shows that most of the factors presented are considered important, the main ones being 'Lack of human resources' (average: 4.09), 'Difficulty in obtaining data for the SCG' (average: 3.81) and 'Lack of adequate training on the SCG' (average: 3.80).

Table 4. Factors hampering the implementation of the SCG.

Factors (N = 101)	Average
Lack of human resources	**4,09**
Lack of financial resources	2,79
Lack of technical resources	3,69
Lack of adequate training on the SCG	**3,80**
Difficulties in interpreting NCP 27	3,27
Resistance to change	3,36
Resistance to the control inherent in the SCG	3,38
Difficulties in obtaining data for the SCG	**3,81**
Lack of involvement of municipal managers	3,64

With regard to the usefulness of the information generated by management accounting, as in the previous question, respondents were asked to assess the degree of use, using a 5-point Likert scale (1 - never; 2 - rarely; 3 - sometimes; 4 - often; 5 - always), and the list of options presented was based on point 4 of NCP 27.

It can be seen that the information generated by management/cost accounting is not yet widely used internally by the municipalities under study. The area in which it is most frequently used is 'in determining prices, tariffs and fees', with an average of 3.01 (Table 5).

4.5 Analysis of Research Hypotheses - Spearman Correlation

Spearman's correlation was used to test the association between the variables.

In this study, a significance level of 5% was used, so if the p-value (in SPPS: sig.) is less than or equal to 0.05, it means that there is a statistically significant association between two variables. On the other hand, if it is greater than 0.05, there is no statistically significant association between two variables ([26]).

Spearman's correlation will only be used in hypotheses 1 and 2.

Hypothesis 1 sought to ascertain whether there was an association between the geographical location of the entities surveyed and the implementation of the SCG.

The aggregation process took into account the fact that the coastal region, between Alto Minho and the Área Metropolitana de Lisboa, has the highest concentration of Portuguese population and the largest number of municipalities.

Table 5. Usefulness of information.

Information use (N = 101)	Average
Budgeting	2,30
Planning, controlling, and justifying a cost reduction plan	2,51

(*continued*)

Table 5. (*continued*)

Information use (N = 101)	Average
Determining prices, tariffs, and fees	**3,01**
Determining the cost of production or asset development	2,72
Measuring and evaluating performance	2,20
In the economic justification of decisions to outsource services	2,49
Comparing actual costs with forecast costs	2,30
Compared to other entities	1,85

In addition, the coastal regions are home to the largest number of higher education institutions and are more likely to teach courses that include public accounting and management accounting curricula. On the other hand, it is in the inland regions where there are often challenges related to the shortage of qualified labor ([6, 11, 19]).

It was possible to see that, contrary to what was expected, it is not the NUTS III of the Litoral (59%) that includes municipalities with a higher percentage of adoption, but those included in the NUTS III of the Interior (75%). The remaining NUTS III also have a higher percentage of adoption, with 70% of the municipalities surveyed.

The Spearman correlation test shows that there is no statistically significant association between the geographical location of the municipalities surveyed and the implementation of the SCG, as the p-value is greater than 0.05 (0.23).

Hypothesis 2 sought to analyze the association between the size of municipalities and the implementation of the SCG. The aim was to see if larger municipalities are more likely to implement the SCG, due to the greater availability of financial and human resources.

The Spearman correlation test shows that the sig. is 0.049, which indicates that there is a statistically significant association between the implementation of the SCG and the size of the municipalities, at a 5% level.

The correlation coefficient is -0.196, which represents a negative correlation, i.e. high values for one variable correspond to low values for another. According to the categorization used: 1 - $\leq$ 20,000 (small); 2 - $>$ 20,000 to $\leq$ 100,000 (medium); 3 - $>$ 100,000 (large), it can be concluded that the implementation of the SCG is more associated with large municipalities and less with small municipalities, as previously highlighted.

5 Conclusions

The SNC-AP requires the implementation of a management accounting system, which is an improvement on the old framework, which provided for the implementation of cost/analytical accounting.

Management accounting is important in the public sector as it helps improve information for decision-making and accountability, evaluates the performance of sectors and managers, improves the allocation function, increases efficiency and promotes cost reduction ([28]).

The results obtained show that 66.3% of the municipalities surveyed have begun the process of implementing the new management accounting system, although this rate is not very significant considering that implementation is mandatory.

With regard to the relationship between geographical location and the implementation of the SCG, there is no association between the variables and, contrary to expectations, it is not the NUTS III of Litoral that have the highest rate of implementation of management accounting, thus rejecting hypothesis 1.

On the other hand, it was possible to verify the existence of an association between the size of the municipalities and the implementation of the SCG, with larger municipalities having a higher implementation rate. Hypothesis 2 is therefore validated.

With regard to what NCP 27 provides in terms of the main instruments, the municipalities followed the recommendation to use the multiple base (59.7%) more than the ABC method (38.7%). It can therefore be said that the municipalities surveyed did not follow the recommendations of NCP 27, which rejects hypothesis 3.

With regard to the disclosure of management accounting information as set out in points 34 and 37 of NCP 27, only 2 of the municipalities surveyed said that they fully comply with this disclosure. Furthermore, although it is compulsory to disclose information on income and results, most municipalities only disclose costs. Hypothesis 4 is therefore rejected.

With regard to the factors that hamper the implementation of the SCG, the main one identified was 'lack of human resources' (average: 4.09), followed by 'difficulty in obtaining data' (average: 3.81) and 'lack of training on the system to be implemented' (average: 3.80). This validates hypothesis 5.

In terms of the usefulness of the information produced by the SCG, it can be seen that its use is still not very significant in the municipalities surveyed, thus rejecting hypothesis 6.

As a limitation of this study and despite the fact that a reasonable response rate was obtained, it was not sufficient to allow the results to be generalized to all Portuguese municipalities.

Another important limitation lies in the data collection instrument, since the questionnaire prevents us from helping the respondent when they don't understand a question correctly. This limitation can be overcome by complementing this study with other instruments, such as interviews.

As an avenue for future research, it is suggested that this study be replicated after the three-year transition period established by IPSAS 33, in order to assess whether there are still municipalities in a situation of non-compliance.

In addition, it would be relevant for this research to focus exclusively on medium and large municipalities, due to the greater homogeneity in terms of available resources, in order to gain a deeper understanding of the implementation of the SCG and the benefits that come from its use.

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Segment Reporting Systematic Review: An ADO-TCM Framework Approach

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Abstract. The relevance of the study lies in the global extension of segment reporting requirements, driven by calls from the investment community and harmonization projects between countries. The article highlights a trend in segment reporting regulation, leading to numerous studies examining practices, determinants, value relevance, and the IASB's IFRS 8 Post-Implementation Review. The objective of the study is to provide a comprehensive overview of existing literature on Segment Reporting, elucidate the methodology used (including bibliometric analysis, PRISMA framework, and ADO-TCM analysis), and present results and conclusions derived from the data analyzed through these methodologies. The study aims to contribute to the understanding of segment reporting practices and their implications for stakeholders in the financial reporting landscape. In the realm of positive outcomes, it is observed that the adoption of a management approach significantly enhances the accuracy of analysts' forecasts. Furthermore, the alignment between segmentation notes and Management Discussion and Analysis (MD&A) proves to be instrumental in augmenting the depth and effectiveness of analysis. Additionally, the implementation of IFRS 8 manifests as a noteworthy positive aspect, bringing about a quantitative upswing in reporting practices. Conversely, a less favorable aspect surfaces concerning the use of non-IFRS segment data. This alternative data source is associated with a decline in the precision of forecasts, concurrently giving rise to heightened levels of uncertainty in the analytical predictions.

Keywords: Disclosures · ADO-TCM · Information · IFRS

1 Introduction

Segment reporting requirements have been extended worldwide in response to calls from the investment community and as part of harmonization projects between countries. Investors and analysts often assert that segment disclosures are among the most important information provided by firms [1]. Additionally, it has been well established that the firm commitment to a high financial reporting quality reduces the information asymmetry between its managers and stakeholders, and between informed and uninformed investors [2].

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For a firm with diversified geographic and/or business operations, it is likely that profitability, resources, and returns will vary significantly across each segment. As such, users of financial reports may find it difficult to identify these differences without additional disclosures related to segments [3].

The importance of segmenting information to both financial analysts and general users of financial reports has been recognised by standard setters around the world. As a result, a series of financial reporting standards governing segment reporting have been issued and revised in response to user concerns [3]. SFAS 131 Disclosures about Segments of an Enterprise and Related Information, issued in 1997 by the Financial Accounting Standards Board (FASB) in the United States (US), is perhaps the most widely recognised standard on segment disclosures. There has also been a corresponding movement at the global level in the International Accounting Standards Board (IASB) with respect to segment reporting. The IASB issued Exposure Draft (ED) 8 Operating Segments in January 2006 to replace the existing standard, IAS 14, and to align reporting requirements with SFAS 131 [3]. According to reference [2], the recent trend in segment reporting regulation (IAS 14R and then IFRS 8) led to a proliferation of studies that examined segment reporting practices, their determinants and their value relevance and usefulness, and the IASB's IFRS 8 Post-Implementation Review.

With this said, the structure of this article goes as follows. In the first section, there will be a broad overview of already existent literature about Segment Reporting. Secondly, the appropriate type of methodology for this study will be explained in detail, accompanied by either tables or figures. This section elaborates the topics related to the bibliometric analysis of previous academic material, the PRISMA framework, and the ADO-TCM analysis, to reach the general objective "Identify the concepts that best describe the current use of Segment Reporting in companies". The last section of this article addresses the results and conclusions according to the data analyzed from the previously mentioned methodologies and analyzes.

2 Literature Review

2.1 Segment Reporting

Regulators and investors consensually defend the need for high-quality financial information, this derives from the fact that the quality of financial reporting directly affects the capital markets, something that is an accepted premise by the community. Combined with poor implementation and a lack of demand for dissemination, the quality of dissemination in the economies concerned will naturally be low [4].

The dissemination of information can enhance what the science of markets is. Of course, traders' predictions about payment are updated by the disclosed pricing information and also provide information on price regulations. The degree of disclosure and the cost of capital are inversely proportional [5]. Segment reporting comes from the need to understand other companies. It is FASB's argument that the information being provided by segments, helps in assessing the cause of the previous cash flows, performance and future prospects of a given company, and the segments are its constituent parts. SFAS 131 in its management approach explains how to identify which operating

segments and financial data to disclose. According to reference [6], the IASB also concluded that SFAS 131 provides more useful information to its users compared to SFAS 14 allowing to increase the number of reported segments and allowing users to see the company through the eyes of Management, decreasing the opportunity for managers to manipulate profits and segment performance measures [7]. These changes arise from the fact that many companies are arguing that they did not have industry segments derived from the broad definitions that previously existed. IAS 14R has some drawbacks: public companies are at a disadvantage compared to private or foreign companies, which do not have to disclose information [8].

2.2 Ifrs 8 & Ias 14 / Sfas 131 & Sfas 14

IFRS 8 reduces the number of information items per segment previously provided for by IAS 14R and requires the disclosure of revenues, liabilities, depreciation, and capital expenditures (see Table 1). The decision to disclose or retain information by segments would not depend only on the rules though, but also on the disclosure behavior adopted by the company in its environment [2].

Table 1. Key Differences between IFRS 8 and IAS 14 (adapted from [7]).

IFRS 8	IAS 14
Business activities that earn revenues or raw expenses whose operating results are regularly reviewed by COMD	Business or geographic based components in terms of risks and returns that are different from other components
Entities whose equality or debt securities are publicity traded or that issue equity or debt securities or financial statements with a regulatory organization for IPO purposes.	Entities that have public traded securities or are no process of issuing then in a public market
Information management uses to run the business	Financial information presented in the consolidated financial statement
Management information reported to the COMD	IFRS – compliant financial information
Reported items are not defined Convergence US	Reported items are defined Segment reporting agrees with financial statements

IAS 14R required the following disclosures for each segment: revenue (external and intersegment), earnings, assets, intersegment price basis, liabilities, capital expenditures, depreciation, non-cash expenses, excluding amortization; income from the equity method, and a reconciliation with the consolidated accounts. For secondary segments, the standard requires disclosure of revenues, assets, and capital expenditures. [8].

Institutions are required to provide this information [5]. Geographic business segments are subject to many risks, such as the impact of technological changes, government policies, exchange rate fluctuation or volatility, international comparative advantages, and political instability causing some disruption in what the adaptation to current regulations is. The disclosure of information is essential, especially so that their stakeholders

can assess performance, potential returns, growth of opportunities and different levels of risk, corresponding to different geographical areas [6]. After the adoption of SFAS 131, there was an increase in disaggregated information by segments and there were reports with a greater number of segments from different companies, although there were exceptions (see Table 2). Thus, it was found that not only an increase in the amount of information, but also a greater adaptation to current needs, according to [9]. With this scenario, central banks are empowered to inadvertently increase adjustment incentives by disclosing even more common information to all speculators [5]. The existing asymmetries in information between managers and stakeholders can be reduced with a high amount of financial reporting, which makes it possible to increase the liquidity of a company's shares. The choice of top auditors may also lead to increases in the quality of information obtained and disclosed, however there is a need for control over managers to limit their discretion in disclosing this information [2].

Table 2. Comparison between SFAS 14 and SFAS 131 (adapted from [7]).

SFAS 131	SFAS 14
Management approach	Industry approach
Operating segment with or not yet with revenues	Focused on an enterprise end products/services sold to external parties.
More specific and detailed: Operating segment and enterprise	Less detailed on industry segment and geographical areas
Some segment information are reported	Required that segment information be reputed on an interim basis

2.3 Some Common Mistakes

Spreading false prospects by reducing uncertainty exposes companies to litigation if the result is unfavorable to them. In this way, its dissemination can be competitively disadvantageous [4]. However, more public information increases the incentives for marketers to train and/or obtain more accurate information. When the risk is low, it is easier to use the information to make trades [5]. Larger companies were exposed to high monitoring costs and thus have an additional incentive to minimize monitoring costs by providing more voluntary, high- quality disclosure. Its results are broadly in line with the predictions of proprietary cost theory explains that when profitability increases, companies have incentives to aggregate their segments by becoming more voluntary [2].

Countries with regulated legal systems have a great deal of political influence in setting accounting standards and practices. It is therefore well known that a shareholder governance model in common law countries encourages faster disclosure of accounting information than the laws of other countries, as it also focuses on stakeholders [4].

The prices that are used in the market end up playing a key role in aggregating more personal information of traders, allowing governments to profit from this knowledge provided by companies. In this sense, public information plays two roles in trading: an informative role and it serves as an adjustment because it helps traders predict future values [5]. Bad news is usually recognized as opportune, since its publication under a law brings with it more reliable information, and therefore useful for external funders. The lack of disclosure of important news can cause market conflicts, revealing a negative impact on its growth, making it less attractive to investors [4]. Such disclosure increases market liquidity and may have a negative effect on investor welfare by destroying trading opportunities [5]. A satisfactory economic outcome may obscure a deterioration in the competitive performance and operating result of one or more segments that are crucial to the success of your company's overall strategy [10].

3 Methodology

Systematic reviews meticulously assess and consolidate the present understanding, offering several benefits compared to narrative reviews. Meanwhile, meta-analyses offer a more dependable and refined precision in estimating effects compared to individual studies [11]. The present work aims to verify, through a systematic literature review, which concepts best describe the current use of segment reporting in companies and how it may be advantageous for companies to maintain segment disclosures with quality. For this purpose, we used PRISMA and the ADO-TCM framework supported by articles from the Scopus database.

3.1 PRISMA Analysis

To identify the current body of knowledge on the impact of adopting the management approach to segment reporting, we conducted a systematic review of the literature. Only peer-reviewed articles published in journals were considered, to consider only the knowledge validated for our review. Introduced in 2009, the Preferred Reporting Items for Systematic Reviews and Meta- Analysis (PRISMA) methodology provided systematic reviewers with a structured set of reporting guidelines [12].

Initially, it involves the identification of all relevant items and the selection of an appropriate database to meet this objective. Scopus was chosen and prioritized as the database for the construction of the bibliographic database. The selection of the best describing keywords ensured that our study obtained the most accurate and comprehensive knowledge on the topic. The keywords in our sample were: "segment reporting", "geographical segments", "Geographic Disclosures", "SFAS 131", "SFAS 14", "IAS 14". Our original sample had 165 items. The second phase of the PRISMA protocol involves conducting a trial process. At this stage, it is crucial to identify and isolate the key primary items of importance. Our goal is to examine peer-reviewed articles. Two (2) articles that were removed because they were duplicates. A total of eight (8) articles were removed because they were not given any opportunity to access them and therefore could not be reviewed. And a total of one (1) were not written in English. As a result, the study ended up with 154 articles after this stage. In the last step, an assessment of

eligibility is made and the inclusion criteria for certain articles are explained in detail. To identify the documents that fit the objectives of the study, a review of the abstract of each item was carried out to verify whether any article did not meet the pre-defined criteria. Fifteen (15) articles that were not related to segment reporting were excluded, and one hundred and nine (109) were removed for being published before 2018. After this procedure, the final sample had 30 (thirty) eligible articles (Fig. 1).

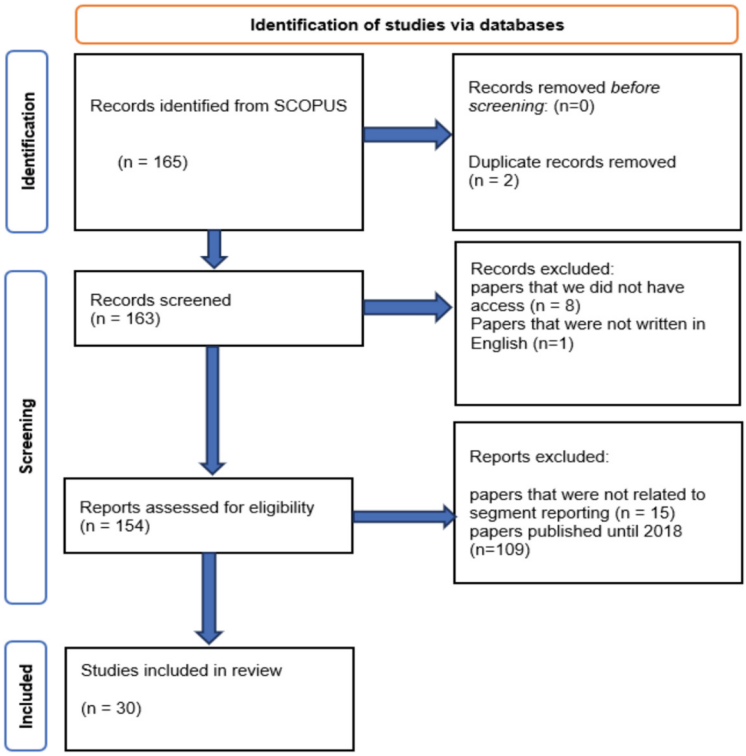

Fig. 1. Prisma Analysis of Segment Reporting Studies

3.2 Bibliometric Analysis

The indicators in bibliometrics heavily rely on methodology, necessitating various forms of data normalization. However, these studies come with several pitfalls; conducting and interpreting bibliometric investigations accurately demands technical expertise, critical thinking, and a thorough understanding of the specific scientific field being examined. And it helps in identifying publications by authors, publication years, the most influential and pertinent journals, the publication countries, and the conclusions drawn from them [13]. Bibliometric analysis is a popular and rigorous method for exploring and analyzing large volumes of scientific data [14]. Regarding the number of citations, the collected articles that were chosen were recently less published and therefore it may be necessary to give a greater focus to the articles published in 2018 and 2019 in order to obtain the

most relevant information related to the topic in question as can be seen below with law in many countries changing over time..

According to Fig. 2, and taking into account the Fig. 3, it is possible to see that the most cited articles were published in Q1 and Q2 journals, which highlights the relevance of the theme, taking into account that the vast majority of articles were classified as Q1 and Q2, with a relevant number of indexed publications.

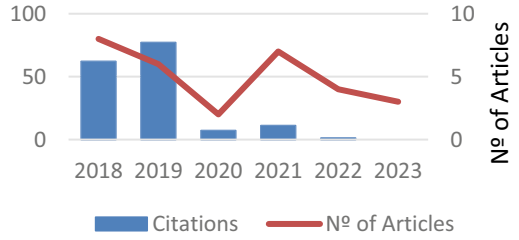

Fig. 2. Citations per article by year

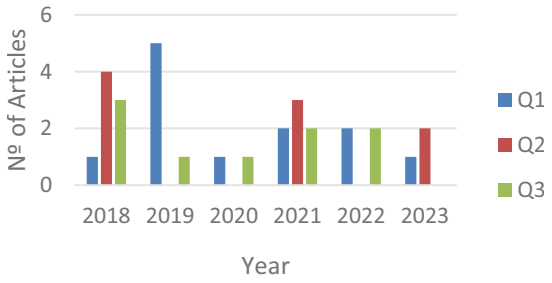

Fig. 3. Articles ranking per year

The journals to which the selected articles belong were analyzed and it was concluded that they are mostly in the Journal of International, Auditing and Taxation with 3 publications and the Journal of Financial Reporting and Accounting with 2 publications that focus a lot on these topics that involve accounting at an international level (Fig. 4).

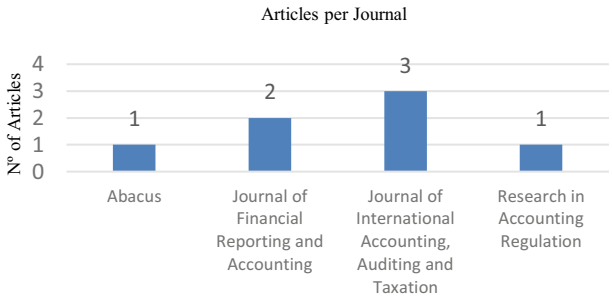

Fig. 4. Number of selected articles per journal

4 Quality Assessment: Readibility

The overall cost of data quality encompasses both the expenses related to assessing and enhancing data quality, known as the data quality program cost, and the expenses stemming from inadequate data quality. Decreasing the costs associated with poor data quality involves implementing a more robust and typically more costly data quality program. Consequently, elevating investment in the data quality program leads to a reduction in the expenses attributed to poor data quality, which can be viewed as the advantage or benefit of having a data quality program. The expenditure on a data quality program can be viewed as a preventive cost borne by organizations aiming to mitigate data errors [15]. It is intended to be a simple and brief quality assessment instrument not only to assist editors in their decisions about manuscripts, but also to help reviewers and readers in their assessment of papers and authors in writing narrative reviews [16]. Quality assessment is crucial as it ensures the reliability and accuracy of the data and analyses presented.

Readability isn´t a concept which can be easily described with precision, and it can be used to grade texts from military instructions all the way up to insurance contracts for example, however above everything else, it´s evolving on school textbooks grading.

Regarding the subjects which we are currently studying, related to accounting and financial matters, other community researchers often measure readability based on what they call the Fog Index. The Fog Index consists of a linear combination between sentence length, and the proportion of complex words. Complex words are currently defined as words with more than two syllables, this criterion is often criticized, considering that it isn't a specified measure.

Table 3. Search results on readability analyzer

	Mean	Std. Dev	Median
Number of sentences	277	1.9	126
Words per sentence	8.8	1.2	4.2
Characters per word	6.4	0.9	3.5
% difficult Words (estimate)	22.8	2.5	15.7

(*continued*)

Table 3. (*continued*)

	Mean	Std. Dev	Median
Flesch Reading Ease	34.6	5.6	58.4
Gunning Fog Scale Level	5.3	1.8	2.7
Flesch-Kincaid Grade Level	4.5	0.5	2.2
Smog Grade	1.3	0.2	0.7
Dale-Chall Score	5.3	1.5	2.4
Fry Readability Grade Level	6.7	0.1	3.1

As much as the Flesch Reading Ease is, it turns out to be easier to read using the number of syllables and the lengths of sentences. The Gunning Fog Scale Level uses the percentage of Foggy words that may contain 3 or more syllables causing possible misunderstandings in interpretation. The Flesch-Kincaid Grade Level measures the possibility for an average student to understand the text. Smog Grade means the age necessary to read and comprehend the topics presented. Dale- Chall score means that if the score is high (close to 10) the concepts are harder to learn or else it could be closer to a lower score of 4.5 (4th grade student). Fry Readability Grade Level is attributing a score each 100 words of text about its complexity. With Table 3, we are able to identify that there is discrepancy between Number of sentences for each article that will be used in SLR pointed by the standard deviation. Sentences find out to be around 9 words per sentence. Flesch Reading Ease means that articles are easy to understand. This was proved by the low Gunning Fog Scale Level and low Flesch-Kincaid Grade Level that the words are simple but the Dale-Chall Score shows that the concepts might be hard to interpret the main findings and results.

5 ADO-TCM

The ADO model is a tool that focuses on the results of previous research in a logical order, it may be insufficient to promote a robust future research direction due to a lack of focus on theories, contexts, and methods. Even if the TCM framework effectively integrates the fundamentals of previous research in obtaining future findings, it cannot even demonstrate the significance of key constructs and interrelationships [17].

According to [18], analysis nowadays makes it possible for investigators to process tens up to a few hundred scientific articles by recurring to qualitative or quantitative techniques. Regarding the quantitative approach it is possible to analyse the content just by quantifying a specific unit to analyse. This result can be obtained combining the following, adopt, adapt, or develop an organizing framework, ADO-TCM constitutes an organized framework. The TCM framework was initially formulated by [19], with each letter representing a component of the framework. “T” signifies theories, encompassing the perspectives that scholars utilize to steer their investigations. “C” denotes contexts, showcasing the specific circumstances considered when exploring a particular topic, while “M” represents methods or the empirical evidence employed in the research. And ADO (Antecedents, Decisions, Outcomes) framework [20].

In addition, the ADO (Antecedent–Decision Characteristics–Outcome) framework and the TCM (Theory–Context–Method) framework are employed to structure and present a conceptual model and future research directions concerning consumer cynicism. This framework aims to address predictors, mediators, moderators, predictands, theories, methods, and contexts associated with consumer cynicism [21].

5.1 Theories

As we can see in Fig. 4, the articles on Segment Reporting used certain theories and models, many of them to help understand the understand the business context, about the operations and prospects of a company. In total, 7 theories and models were used in the sample. One of the most interesting models used is the ABSC production decision model [22]. The ABSC production decision model can help our entity's CODM to conduct the business' two core principles: One for following the business activities of products to define the operating segments of products; another for measuring the reportable segments of revenue to disclose the financial information of revenues and expenses in each product area for each period [22]. A powerful theory for the Segment Reporting that was used in the articles in the sample is the Decision-Usefulness theory, that has been widely utilized, especially in understanding financial reporting. Identifying the decision-makers and the accounting information's relevance to various groups of users are two key fundamentals underpinning the theory [22].

5.2 Contexts

In the articles and papers about Segment Reporting that have been analyzed for this study, in it‘s majority the focus seemed to be concentrated the most in European Union, (which is the of [23, 24], and [2]). Since there is a substantial variation in the quality of segment reporting among the sampled European Union firms. Large corporations, audited by Big 4 auditors and more internationally oriented, tend to provide a higher quality of segment reporting [2].

5.3 Methods

When it comes to the methodology used in the articles analyzed, it can be seen through the TCM framework that several methods have been chosen, namely quantitativeand qualitative methods. When it comes to the quantitative methods, content analysis (for example [25]), to investigate how financial analysts implement the Sum-of-the-Parts (SOTP) valuation framework. On the other hand, the qualitative methods that have been most used are documental analysis (for example [26]) (Fig. 5).

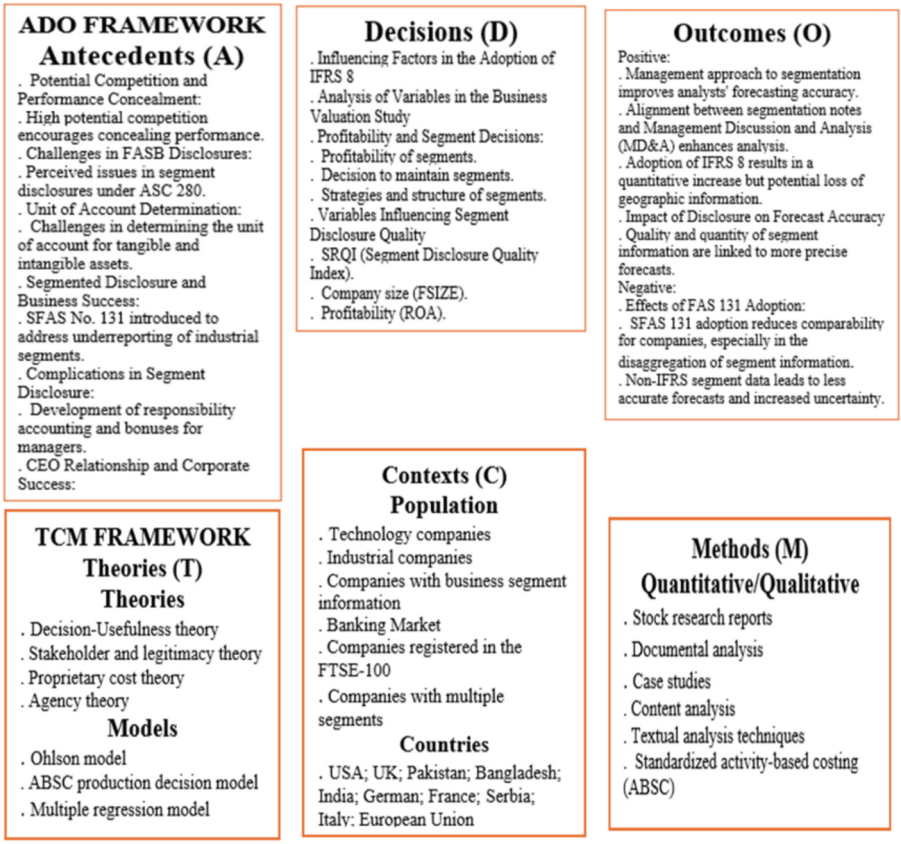

Fig. 5. ADO-TCM framework for Segment Reporting studies

5.4 Antecedents

Drawing upon the analyzed articles, we were able to identify various antecedents corresponding to the compilation of articles used as a basis for the literature review. According to Fig. 1, some of the key antecedents identified include: high potential competition encourages concealing performance, and the hiring of CEOs influences corporate success. Explicitly considering different types of competition in the product market by distinguishing between established competitors in a specific market and potential competitors contemplating market entry, as discussed by [27]. We argue that companies facing intensive existing competition have fewer incentives to conceal information, as the likelihood of abnormal profitability is reduced. Conversely, a high level of potential competition poses a threat to profitability and, therefore, provides incentives for concealing segment performance.

5.5 Decisions

Having comprehended and analyzed the antecedents, the focus shifts to the variables addressed in the studies considered in this investigation. The variables deemed most relevant include Influencing Factors in the Adoption of IFRS 8, SDQI (Segment Disclosure Quality Index), Firm size (FSIZE), and Profitability (ROA). The effective implementation of IFRS 8 in a nation is determined by various factors, as emphasized by [23]. These factors encompass the prevailing legal system in the country, the degree of effective law enforcement, measures for investor protection, the adopted accounting conservatism, and the alignment between national accounting practices and the standards set by IFRS. These elements play a crucial role in the proper incorporation and acceptance of IFRS 8 within the accounting and regulatory framework of each country.

On the other hand, [28] observes that the implementation of IFRS 8 and its impact on the cost of capital are explored topics. The study investigates how the adoption of IFRS 8 influences companies' capital costs and examines the moderating role of the national-level regulatory system in this relationship. The author analyzes how the quality of the regulatory environment, especially the effectiveness of the regulatory system, modulates the effects of adopting IFRS 8 on organizations' cost of capital. In the study conducted by reference [2], various variables were employed to assess the quality of segment disclosure by companies. The researcher utilized SDQI, an index measuring the quality of segment disclosure, along with variables such as FSIZE (firm size), ROA (profitability), LEV (leverage), EXPORT (degree of internationalization), Big4 (related to audit quality), and CONTROLS (encompassing control variables).

In addition to these variables, the model also incorporated IFRS 8, an international standard governing financial reporting, aiming to understand how these factors influence the quality of corporate segment disclosures.

5.6 Outcomes

Regarding the outcomes obtained in the analysis, we consider the following as most relevant positive aspects: Management approach to segmentation improves analysts' forecasting accuracy; Alignment between segmentation notes and Management Discussion and Analysis (MD&A) enhances analysis; Adoption of IFRS 8 results in a quantitative increase but potential loss of geographic information. And the most relevant negative topic: Non-IFRS segment data leads to less accurate forecasts and increased uncertainty.

The study [29] highlights a significant relationship between enhanced reporting of corporate segment information and the presence of robust governance, coupled with timely loss recognition. Managerial choices in data aggregation also impact accounting conservatism. In summary, the chosen approach in data aggregation directly influences the readiness for identifying economic losses, emphasizing the interconnection of these elements with segment variability and overall corporate governance quality. According to [30], the adoption of IFRS 8 resulted in an average increase in the number of segments reported by companies.

Using the variable CHANGESEGi to assess changes in segmentation, the study suggests that the impact on the informational environment varies based on the type of change in the number of segments. The managerial approach of IFRS 8 aims to enhance

the informational environment through these segmentation changes. As per [31], the use of non-IFRS segment data is associated with less accurate forecasts by analysts.

These data are linked to greater dispersion and uncertainty in predictions, contributing to lower precision in the public information set provided by analysts. According to [32], the management approach to segmentation has a positive impact on the average accuracy of individual analysts' forecasts and the overall accuracy of available information.

6 Discussion

With the results and the previous literature review we found that the importance of transparent and accurate segment reporting in financial disclosures, the impact of regulatory frameworks such as IFRS 8 on company practices and market outcomes, and the interplay between management decisions, governance quality, and forecasting accuracy in financial analysis having advantages as described by [8].

Furthermore, the trade-off discussed in reference [2] between the advantages of informing by improving capital market conditions and the disadvantages in terms of costs to be borne corresponds to the considerations regarding the adoption of IFRS 8 and its impact on companies' capital costs, as mentioned in [28]. This demonstrates how managerial decisions on segment disclosure can have significant implications for various aspects of financial reporting and market conditions, as discussed in both passages.

The increase in the number of companies providing dissemination services by segment, as indicated by the proportion of disclosures by geographical segments at the country level increasing while disclosures by wider geographical areas decreasing, implies a shifting landscape in segment reporting practices. In summary, the need for improvement in segment reporting practices, as highlighted in Stojanović Aleksić (2016), relates to the application of theories and models to enhance the usefulness of segment reporting information and the outcomes observed in segment reporting practices, as discussed in the "Theories" and "Outcomes" sections, respectively.

Additionally, the emphasis on variables and decisions related to segment reporting quality, such as the adoption of IFRS 8 and the assessment of influencing factors, reinforces the imperative for continuous improvement. These decisions reflect the ongoing efforts to refine methodologies and adapt to regulatory changes, thereby enhancing the reliability and usefulness of financial reporting.

Overall, the quote's assertion regarding the constant need for improvement in accounting theory and practice resonates throughout the subsequent discussions, emphasizing the dynamic and evolving nature of segment reporting and its broader implications for accounting methodologies. Several concepts that influence this practice are highlighted, such as the adoption of IFRS 8 and the influence of regulatory factors and the legal environment. In addition, the text mentions the importance of tools such as the Segment Disclosure Quality Index (SDQI) and considers variables such as the size of the company and its profitability. The strategic approach of management is also pointed out as a relevant factor for the quality of reporting by segment.

In summary, these concepts offer an in-depth understanding of current reporting practices by segment and highlight the complexity and importance of this area in business accounting.

7 Conclusion

For this study, 30 studies that are related to Segment Reporting were identified. These articles along with the bibliometric analysis that was conducted helped to reach the general objective of the research established. This study then used two frameworks that helped organize the data for a better understanding of previous literature: the TCM and the ADO frameworks. Their use made the study more complete, and it offered a clearer way to see the outtakes from the articles chosen for the bibliometric analysis.

With the use of ADO framework, this study reached the general objective "Identify the concepts that best describe the current use of Segment Reporting in companies" being able to identify antecedents (reasons that highlighted aspects of segment reporting), decisions (which variables are most used in articles) and outcomes (what the consequences and the impacts of Segment Reporting implementation). The specific reasons that we identified about the aspects of segment reporting are, "Potential Competition and Performance Concealment", "High potential competition encourages concealing performance", "Challenges in FASB Disclosures", "Perceived issues in segment disclosures under ASC 280", "Unit of Account Determination", "Challenges in determining the unit of account for tangible and intangible assets", "Segmented Disclosure and Business Success", "SFAS No. 131 introduced to address underreporting of industrial segments", "Complications in Segment Disclosure", "Development of responsibility accounting and bonuses for managers", "CEO Relationship and Corporate Success", "Hiring of CEOs influences corporate success". It was also with the use of the ADO framework that we found the variables that are most used in articles. Previous literature shown us that aspects such as "Profitability of segments", "Decision to maintain segments", "Profitability (ROA)", "Company size (FSIZE)", "Variables Influencing Segment Disclosure Quality", that are extremely important to analyze the aspects of segment reporting.

Lastly, the ADO framework let us organize the outcomes of segment reporting. The impacts are divided into positive and negative. Some of the positives are "Adoption of IFRS 8", "Impact of Disclosure on Forecast Accuracy". Some of the negatives are "Effects of FAS 131 Adoption", "SFAS 131 adoption reduces comparability for companies, especially in the disaggregation of segment information".

Using the TCM framework in this study was crucial to identify the theories and models that have been used in previous literature, as well as contexts (countries and the population) in which the literature focused on, and the methods that were used. Some examples of the theories and models related to the Segment Reporting are *Decision-Usefulness theory*, *Stakeholder and legitimacy theory*, *Proprietary cost theory*. The TCM framework also helped us conclude that the main targets of Segment Reporting studies were "Banking Market", "Companies with multiple segments", "Technology companies" in regard the population, and countries such as Italy, France, German, due to the extensive sample of companies with Segment Reporting. In order to follow out previous studies and come to important conclusions, previous researchers used certain quantitative and qualitative. This study concluded that *Stock research reports*, *Documental analysis* were the most used ones. The qualitative research also sought to reach the general objective. Which included addressing segment reporting, the differences between IFRS 8 and IAS 14, and SFAS 131 & SFAS 14. And finally, the dissemination of information.

Contributions. This study will contribute to numerous important aspects. First and foremost, this study will guide future scholars in conducting more targeted investigations and contribute to a better understanding of Segment Reporting. Synthetizing the bibliometric analysis with the TCM and ADO frameworks will make it easier for researchers to understand what has been studied and what really needs to be further developed. Adding to this, this study will also contribute to the academic and overall knowledge and understanding of Segment Reporting by showing aspects such as antecedents, impacts and outcomes in this topic.

Limitations and Recommendations. Regarding the ADO and TCM frameworks, it is essential to note that most studies were focused on specific topics, places and different ways of engaging in Segment Reporting. Therefore, the conclusions were not based on this topic as whole, but on specific countries and population. In future research, it is important to understand the impact that Segment Reporting has overall.

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The Role of the Sustainable Development Goal 4 in Sustainable Education: A Literature Review

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Abstract. This study aims to analyse the evolution of the literature following the publication of the Sustainable Development Goals (SDG) and, more specifically, assess the relationship between SDG 4 and the quality of education. The methodology used to carry out this research consists of a literature review seeking to reflect on the aforementioned relationship. This study contributes to the growing literature on the quality and gratuitousness of education and the substantive meanings that SDG4 has had in this growth. The relevance of the study lies in the subject's present relevance. The results suggest that there is a lag in introducing and/or implementing the necessary changes in the education system, and the timely publication of national education policies is a crucial need for promoting these goals. Achieving the goals of SDG 4 is a shared responsibility between individuals, education and training institutions, and regulatory governments.

Keywords: Accountants · Accounting · Artificial Intelligence · AI · Education 5.0 · HEIs · SDG 4 · Teaching · Technologies

1 Introduction

The Sustainable Development Goals (SDGs) are at the forefront of government initiatives worldwide. They are primarily concerned with promoting sustainable growth by ensuring well-being, economic growth, environmental legislation, and academic progress [1]. Accordingly, there is a need to understand whether inclusive and equitable quality education and promoting lifelong learning opportunities for accountants (see SDG 4) are being ensured in an era of rapid change and transformation.

Higher education institutions can play an important role in achieving SDG 4. Considering different challenges and opportunities, higher education can advance SDG 4 in a realistic and meaningful way (see Ferguson and Roofe [2]). Despite the formulation of targets that emphasise inclusion, quality and equity at all levels of education, the development of global indicators for SDG 4 has resulted in metrics that do not address

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many of the values of the targets, particularly concerning the quality and freedom of education and the substantive, not just distributive, meanings of equality [3]. Research should, therefore, address ways of exploring the measurement of the many meanings of quality and equality in education while allowing a reflection on the use of numbers to impose power and hierarchy. Fostering critical dialogue and strengthening participation, responsibility, and work to change injustices in education is essential [3]. At the same time, integrating digital transformation into research and sustainability accounting to improve decision-making has been stressed in recent years. Different ways to explore the interaction between accounting, digitalisation technologies, information systems, and environmental protection have been suggested [4]. Hence, the following research question emerges: How has the literature on the relationship between SDG 4 and the quality of education evolved?

In order to address this article's goal, a literature review aiming to identify, collect, and analyse the main contributions and/or publications on the subject under study was carried out. This analysis allows us to get to know the scientific production, to analyse the contributions made, the conclusions drawn, and the directions for future research.

The article proceeds with Sect. 2 devoted to the literature review. Here, the evolution of the literature about SDG 4 in Quality Education is presented. Then, in Sect. 3, some concluding remarks are offered, encompassing a critical approach to such evolution, the study's limitations, and cues for further research.

2 Literature Review

2.1 Sustainable Development Goal 4

In 2015, the United Nations Sustainable Development Summit launched the SDGs, adopting a universal approach to the Sustainable Development Agenda (Agenda 2030), ushering in a new era of global development goals to solve the most pressing problems[1]. The 17 SDGs outlined in the UN's 2030 Agenda (Fig. 1) are an urgent call to action for all countries to take steps to improve human well-being and to identify initiatives that promote economic development and world peace. Specifically, the SDGs recognise that countries must adopt policies that improve health and education, reduce inequality, and stimulate economic growth, while taking into account the environment and its natural resources [5].

There has also been a rapid increase in the advancement of AI since 2015, which continuously changes the business of organisations and accounting firms. Organisations tend to rely less on human capacity, as AI reduces the likelihood of errors [6]. AI facilitates and enables efficient data analysis and sharing between organisations and countries, which promotes global collaboration and cooperation to achieve the SDGs through sustainability accounting. Sustainability accounting, along with digitalisation, can thus help organisations achieve the SDGs [7].

The new 2030 Agenda for Sustainable Development is universal, holistic and indivisible, focusing on ensuring that no one is left behind [8]. It reflects the vision of the importance of an adequate education response, with the stand-alone Goal 4 - Education -

[1] https://www.un.org/sustainabledevelopment/.

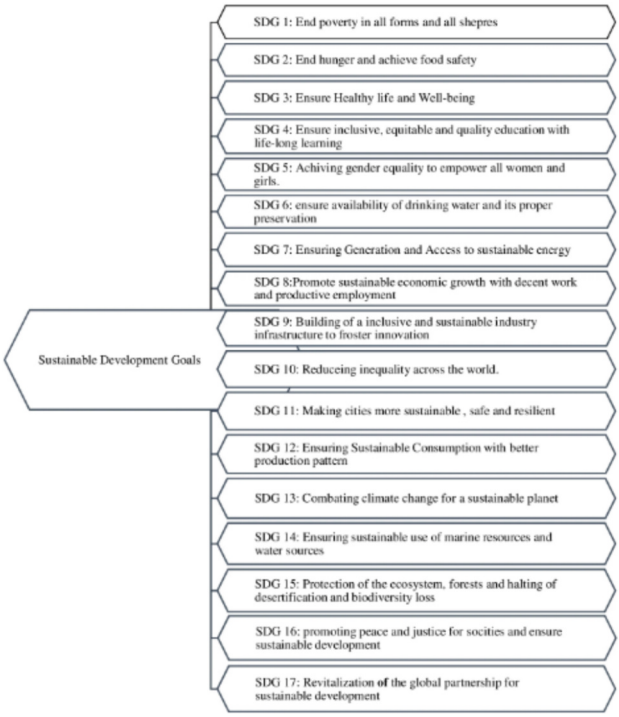

Fig. 1. Sustainable Development Goals (Saini et al., 2023).

comprising numerous targets and indicators as a means to achieve all other SDGs. SDG 4 represents an essential strategy in the pursuit of the SDGs as a key enabler of sustainable development [9, 10], aiming to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all [1, 8].

Figure 2 shows that although research related to SDG 4 has increased since 2018, the only peak was verified in 2023. This means that although the goals and seven targets for SDG 4 were agreed upon in 2015, the struggle over the meaning of quality and equity has continued, partly obscured by the politics of consensus building at different stages of education [3].

2.2 The Contribution of Institutions to Quality Education

One of the most prominent goals of the SDGs is to provide students with quality education (SDG 4), which will subsequently help address issues related to other SDGs. However, there is a need to modify existing policies to ensure the effective implementation of the SDG 4 goals [1]. Education is a key driver in aligning society with the spirit of the SDGs and is well-placed to promote sustainable values, attitudes, and actions for the next generation, which is key to achieving the SDGs [11]. SDG 4, within the framework of the Sustainable Development Programme, is motivated by providing quality education by removing the barriers of poverty, funding, expensive education, discrimination, and unavailability of resources [1].

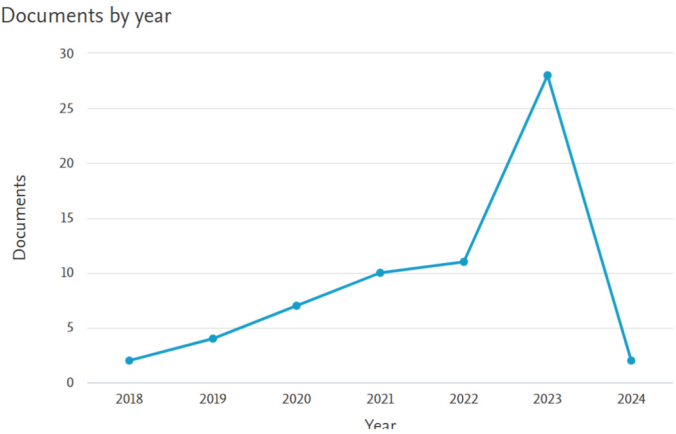

Fig. 2. Research on SDG4 – Evolution[2]

Therefore, higher education institutions (HEIs) play a major role in the attainment of SDG 4. HEIs need to prepare graduates whose awareness goes beyond the boundaries of their academic specialisation and traditional curricula. They must train a new generation of leaders prepared to face the complex challenges that the 21st century poses to business and society [12]. HEI sustainability initiatives are essential to mobilise commitment to education and promote research for sustainable development [1]. By being fully engaged, HEIs can help shape and lead the SDG 4 agenda [2].

Regarding the specific case of accountants, their social capital is particularly valuable [12]. In addition to their traditional roles, accountants should consider how they can contribute to business resilience and influence organisations to integrate sustainability into their organisational strategy [13]. According to IFAC [14], accountants have a key role to play in integrating sustainability into business, as they have an integrated approach to financial and non-financial information, particularly that related to sustainability. Scarpellini [7] states that sustainability accounting could help companies in circular business models by introducing specific sustainability accounting and reporting metrics needed to disclose performance information.

In addition, with the advent of new digitalisation tools, information and communication technology (ICT) skills alone are insufficient to understand the impact of technology on organisations in terms of strategy, cost efficiency, governance, and risk, changing the role played by accountants which have to attend to new demands by their clients. Similarly, low levels of social capital and emotional quotient will lead to ineffective teams, a lack of understanding of client needs, and a lack of trust, negatively affecting future projects and engagements [12]. In this sense, it is educational institutions that must provide support for students and professionals to deal with the digital age, whether at the level of subjects and courses to be learned or renewed, at the level of classroom learning methods and systems, at the level of teacher training, or at the level of facilities

[2] This figure was developed based on the following research strategy: a search for the keyword 'SDG 4' was conducted in the Scopus database, limited to articles and books in the field of business.

to support the learning process [15]. Nowadays, higher education institutions need to incorporate the topic of AI in accounting and management courses to provide students with skills in the field of digital technologies [16]. Likewise, it is important to educate not only students but also the civil community about the importance of organisations' non-financial reports, something which can provide a comprehensive understanding of an organisation's performance and its social and environmental impacts [17].

2.3 A Sustainable Accounting Education

The accounting profession is undergoing radical change, replacing many of the historic accounting roles and requiring the addition of technological competencies to the accountant's skill set [18]. Accounting education should thus consider market demands for the skills and knowledge required of professional accountants and adapt the accounting curriculum and teaching methods accordingly [19]. However, there are still some barriers, obstacles, and inertia of higher education in the soft skills of accounting studies, namely the lack of appropriate equipment, the lack of teachers' ability to simulate real-life situations, and the lack of a continuous, diverse and differentiated (inclusive) assessment model [20]. Hence, building networks between stakeholders both at the university and the workplace could better prepare students and early career accountants for new technologies [21]. Accounting education should thus focus on establishing strong and effective relationships with various entities, such as professional bodies, employers, educational institutions, or communities [20].

It is also crucial to assess factors that limit knowledge, simplification of processes, and progress when developing new skills. These constraints limit and condition the adoption of new reforms that could benefit from specialised accounting knowledge in the use of digital tools and in preparing financial and non-financial reports to communicate information to citizens and other stakeholders [22]. This situation is more pronounced in developing countries, where the digital gap is significant and digital inclusion and infrastructure for online education are at a precarious stage. In such countries, where regional competition and globalisation are driving technological reforms and a push for internationalised education, ICT can play a critical role in ensuring the sustainability of quality education [23]. However, while the adoption of new technologies, such as cloud computing, has increased in developed countries' organisations, the adoption rate has stagnated in certain areas of the globe, such as in sub-Saharan Africa. Yet, cloud computing has the potential to accelerate the pace of digital transformation in that region [24].

Hence, it is necessary to invest in human, technical, and financial resources to reduce and overcome these gaps and difficulties, which hamper new reforms and implementation processes due to the lack of professional skills and knowledge not covered by education and training systems in this digital age. The development of study programs is a joint responsibility of professionals and universities. The aim is to provide up-to-date study programs that cover current topics in the workplace and integrate relevant skills into the educational program. Policymakers must pay closer attention to any misalignment between education and the labour market. The demands of the 21st century require a better-prepared workforce, and academia must be ready to meet this need [25].

Accounting programmes worldwide have not yet sufficiently integrated new ICT knowledge and skills into the curriculum. Although the digital revolution has provided exciting new challenges and research opportunities, Accounting Information Systems (AIS) research has made limited contributions to accounting or information systems research and practice. In fact, there is still a lack of knowledge about the impact of technology on all areas of accounting, auditing, and taxation [26]. Given the highly technical nature of the content of the AIS course, it is necessary to understand whether classroom or computer lab teaching methods lead to improved learning. Class size is a critical issue in today's environment of limited resources, as are student characteristics. It is important to understand the student's perspective and whether it can help integrate AIS topics throughout the curriculum in a way that coordinates topics and reinforces concepts [27]. However, while Saputra et al.'s [28] study concluded that training and education positively and significantly affect AIS performance, Purba et al.'s [29] study concluded the opposite. In other words, the implementation of an AIS is not significantly impacted by education or training. Instead, personal technical skills, user involvement, accounting experience, and senior support drive successful implementation. Hence, education programs should aim to enhance the familiarity of accounting graduates with digital technologies and public finance statistics, thereby improving their employability skills and supporting the transformation of public entities. Curricula and training programs should include budgetary, financial, legal, political, and statistical aspects to develop individuals capable of managing and monitoring sound procurement processes and fiscal, budgetary, and auditing issues [14].

On the other hand, institutional investors and a sustainable university funding model could revolutionise the financing of education systems and directly contribute to social development, particularly in achieving SDG 4 - quality education [8]. Reflections on SDG 4 figures and indicators can facilitate critical dialogue, increase participation, and promote accountability in efforts to address educational injustices [3].

Education 5.0 is a transformation, a new curricular reform intelligently integrated with the potential use of AI and ICT for educational development. It requires the adherence of educators for a harmonious implementation of 21st-century skills, such as learning skills, literacy skills, and life skills [30]. These educators must promote change and transformation, mobilise synergies, and train capable professionals. However, when adopting AI technology, ethical awareness and responsibility should be promoted by encouraging collaboration between humans and AI, developing long-term ethical strategies, providing ethics training and awareness, and complying with regulations [31].

In addition, education systems must address the urgent need for change by establishing pertinent learning objectives and content, implementing pedagogies that empower students, and urging institutions to integrate sustainability principles into their management structures [10]. Education 5.0 is a personalised approach to education that emphasises skills such as communication, leadership, resilience, curiosity, and critical and creative thinking [32].

3 Concluding Remarks

The recent technological advancements have brought significant changes to the educational process to meet the market's demands. Investing in the education system reflects a country's growth potential and culture of innovation. SDG 4, which aims to provide inclusive and equitable quality education and promote lifelong learning opportunities for all by 2030, clearly reflects education goals. However, it is important to note that while education quality, equality, and inclusion may not be easily measurable, they must be integrated into the education system as they are crucial for strengthening human rights agendas and developing strategies to combat injustices. Although research related to SDG4 has been increasing in the past few years, namely since 2018, further research and discussion are still needed to support the development of policies, practices, and accountability to achieve the vision of SDG 4, as stated by Saini et al. [1]. The timely publication of national education policies is crucial to promoting the necessary changes in our education system. It is important to avoid lagging in these efforts.

On the one hand, this study contributes to the literature on education, especially accounting education. On the other hand, it aims to create awareness of the theme among government and public decision-makers, associations, educational and training institutions, and the community in general. More specifically, it contributes to shedding light on the importance of implementing a new type of education that is suitable for current challenges. In practical terms, it can increase awareness of the topic among decision-makers, such as regulatory bodies, who can take preventive measures and modify existing policies to ensure the effective implementation of SDG 4. Additionally, it contributes to Academia by stressing the importance of SDG 4 and its role in promoting sustainability from an accounting education perspective. This study is not without limitations. It focuses solely on the objectives and targets of SDG 4. It is important to note that achieving a sustainable environment requires an integrated approach to all SDGs. Hence, further research should explore the implementation of all SDGs, assessing their relationship with new technologies, especially AI.

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Accounting Information Systems in Quality Education

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Abstract. This study aims to analyse the evolution of Accounting Information Systems (AIS) literature in the new era and its impact on the quality of education. The methodology used to carry out this research consists of a literature review. This study contributes to the growing literature by providing a reflection on AIS in the quality of education. The study's relevance is attributed to the topical nature of the subject. The results suggest that government and public decision-makers, associations, education and training institutions, and the community should collaborate to achieve educational quality with social implications.

Keywords: Accountants · Accounting Information System · AIS · Artificial Intelligence · Education 5.0 · Technology

1 Introduction

Accounting is the information system that measures business activity, processes the information into reports, and communicates the results to decision-makers. Although this system can be manual or computerised, it traditionally uses information technology. Given the intense level of competition in the age of information and globalisation, companies must carry out their operational activities effectively and efficiently to maintain their finances and existence [1]. Technology is, therefore, the key factor in maintaining the competitiveness of industries, specifically when information plays a vital role in decision-making. The use of Information and Communication Technology (ICT) is crucial for organisational strategic decision-making [2]. Through accounting software, data can be efficiently collected and analysed so that timely decisions can be made and organisations can swiftly respond to the market [3].

In an era of globalisation, the development of technology, accompanied by the development of technology-based information systems, has undergone rapid changes [4]. With the development of digital technologies, academics and industries are moving into

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the information age, where data processing is the accounting industry's biggest challenge [3]. Digital transformation is a recent and complex phenomenon in the accounting market, and its impacts on organisational structures require in-depth analysis [5]. The *development of the internet itself has influenced the development of accounting and Accounting Information Systems (AIS), which have had significant growth and evolution in recent times [6]. AIS can be considered as a subsystem of organisational management information systems [7].

Accountants are a valuable, rare, inimitable, and non-substitutable resource that, when combined with generic human capital and digital human and social capital resources, result in highly valuable synergies for organisations [8]. Consequently, the accounting profession has focused significant attention on the best ways to educate students for successful careers, in particular regarding the importance of AIS topics in accounting education [9]. The impact of technology on AIS, AIS ethics, and the application of International Public Sector Accounting Standards (IPSAS) are just some of the subjects that have been the focus of AIS research [6]. Technological advances have effectively enabled and improved the operating procedures of various professions, with the ICT sector being the one with the greatest use of generation 4.0 and 5.0 technologies. This change in the business environment has impacted the accounting discipline, which is expected to change substantially over the next two decades [2]. This will require accountants to have high-level technical and computer skills. ICT skills will be one of the basic technical skills required of accounting graduates [10]. However, Higher Education Institutions (HEI) may be failing to provide students with the broader competencies they will need to deal with the dynamics of change in a complex working environment [11]. Therefore, the relevance of AIS in the Industry 5.0 paradigm of autonomous production with human intelligence is limited, except for its contribution to reducing accounting errors caused by human error [12]. This raises the following research questions: What is the state of the art of Accounting Information Systems, and how does it impact education? Accordingly, this article aims to assess the scientific production on AIS and analyse its contributions, conclusions, and directions for future research developments.

A thematic analysis, which is a qualitative approach widely used to analyse interviews or written documents, was conducted. It allows researchers to investigate the content of the literature and address research questions [13, 14]. Data were collected from Elsevier's "Scopus" database, which is widely covered and validated by the academic community [15]. The "Google Scholar" search engine was used to complement the search. Despite the lack of quality control of publications, the Google Scholar database is also an important source of data [16].

In the next section, the literature review is presented. This section addresses AIS as agents of change, the impact of AI on AIS, and the new challenges accountants face. Then, in Sect. 3, some concluding remarks are offered, encompassing a critical analysis of the results, the study's limitations, and cues for further research.

2 Literature Review

2.1 AIS as Agents of Change

Technology is the agent of change on a broader level, transforming organisations, individuals, customers, suppliers, and governments [5]. Work automation includes data sampling, risk analysis, transaction validation, detailed testing, event matching and anomaly detection [17].

In the current era of modernization, AIS is deemed a system used to accumulate, create, and store information to create information for decision-makers, including people, information procedures and policies, software, IT infrastructure, internal control, and security actions [1]. It is a system that converts business transaction data into useful financial information for the user [18], being used as a basis for decision-making [4, 19, 20]. Its purpose is to measure the financial performance of an organisation's business and the performance of organisational accounting functions [7]. It also aims to support the company's day-to-day operations, assist in decision-making, and meet accountability obligations [18]. AIS allows accountants to process large volumes of financial data efficiently [7] in a timely, accurate, and reliable manner [4]. Organisations tend to adopt and implement AIS due to the advantages in increasing the functionality of accounting departments [7]. In fact, AIS plays a vital role in promoting the effectiveness of management control [21]. Also, it can allow a better allocation of resources, reduce fraud and corruption, and improve accountability and transparency in financial reporting [19].

A good AIS, which can be used by managers in their decision-making or by external parties, can determine the sustainability of the business by helping companies carry out operations and information processes more effectively and efficiently [20].

Due to changes in the corporate environment and technological advances, AIS has undergone substantial modifications over time [6], and it is essential to understand how institutional change can influence AIS research [5]. AIS is a constantly evolving field that combines accounting science with technology to adapt to the current digital transformation [22]. The evolution of AIS demonstrates its fundamental role in providing useful information for efficient decision-making [23].

The performance of AIS is evaluated based on whether the information received meets the expectations of information users and satisfies them. Therefore, developing AIS is crucial for companies to enhance their performance in processing and obtaining information in organisational activities [1]. To stay current with technological advancements, managers require ongoing training and education to enhance their capacity to effectively use technology in decision-making processes [23]. From another point of view, well-designed curricula that meet the needs of the accounting profession in mastering new technological and intellectual challenges should be developed [22].

2.2 The Impact of AI on AIS

It is expected that significant technological changes in financial information will occur over the next two decades due to the widespread adoption of big data, blockchain technology, cloud computing, AI, and machine learning [2].

AI is undergoing a radical transformation and is rapidly becoming one of the most advanced developments in the world. Its effects can be seen in many domains, including business, medicine, education, home automation, social sciences, and impact research [24]. The rapid advancement of AI in accounting has led to increased use of technology, raising ethical concerns that must be addressed before its widespread deployment. Due to the significant impact of AI on the accounting profession, organisations' accounting practices require a distinct strategy that considers the diverse cultural and legal contexts in which they operate. Work automation involves various processes such as data sampling, risk analysis, transaction validation, detailed testing, event matching, and anomaly detection [17]. Integrating AI with other automated information systems can significantly enhance accounting practices. This can provide accurate and reliable accounting information, enabling organisations to demonstrate responsibility, accountability, and transparency. As a result, it can play a crucial role in deterring corruption and promoting public trust in this field [2].

Like any new technology, AI has generated both enthusiasm and scepticism due to its powerful capabilities [17]. Nevertheless, Al-Sammarraee and Alshareeda [25] stress the importance of implementing AI techniques in AIS to enhance the efficiency and effectiveness of these systems, emphasising the need to improve the scientific and practical qualifications of accountants at universities.

When used to record transactions and provide data for internal reporting, external reporting, financial reporting, and trend analysis capabilities, AIS is often considered less useful in business decision-making due to its focus on the past [20]. Since accounting is based on daily business and commercial transactions, new technologies such as IA can reduce task time, leaving humans to solve other accounting and management tasks [26]. Thus, AI innovations have the potential to revolutionise the financial and accounting sectors by relieving financial staff of time-consuming tasks, allowing them to focus on more important responsibilities [24].

AI systems allow accountants to manage larger volumes of financial data and predict future outcomes for the organisation. AI can analyse financial data, automate various activities, and provide valuable insights to improve decision-making. It can detect anomalies in large data sets to identify harmful activities and make predictions using past financial data and external factors. It can also assist in identifying tax optimisation opportunities and ensuring compliance with local and international regulatory frameworks and tax laws [17].

Hence, accountants will need to recommend effective actions to address knowledge gaps before they become a problem [2]. In the future, the work of accountants will be characterised by increased networking, both between individuals and between individuals and AI. This will require openness, flexibility of thought, and interdisciplinary collaboration. Anticipating change, implementing it, and ensuring that future employees have the necessary skills to deal with digital technologies are essential prerequisites for achieving a continuous and successful change process in accounting [27].

The Impact of technological advances on the content of accounting and financial reports has prompted discussions on the implications of these enhancements for accounting professionals [2]. However, the successful application of technology and new techniques in accounting fields will require different skills than those traditionally taught in business schools [28].

2.3 New Challenges for Accountants

The revolution in information technology has impacted accounting practices, leading to an increased demand for accountants with adequate ICT knowledge and skills [29]. AI is a crucial factor in the effectiveness of automated AIS. Undoubtedly, AI has made significant progress in recent years, resulting in remarkable advancements in various fields of study [24]. Hence, for AISs to be effective, they must combine well-qualified human resources with the best software, hardware, and databases [30].

Accountants are a valuable strategic resource due to their unique capabilities of combining generic human capital with the resources of digital human capital and social capital [8]. They act as agents of change, innovation, resilience, and sustainable development advocates. However, some researchers have claimed that accountants are currently hesitant to take the lead in the digital transformation of accounting. This reluctance may result in reduced legitimacy of accountants due to a lack of digital knowledge, the lack of know-how [31].

As a curricular transformation, Education 5.0 intelligently integrates the use of AI and ICT for educational development. This will contribute to the harmonious implementation of 21st-century skills with the support of everyone involved [32]. Training and education can enhance human resources' performance, skills, and knowledge, which are particularly useful for improving user performance and minimising errors when operating AIS applications [1]. As agents of change, accountants require a broad and deep knowledge base, which they can acquire through training and education. However, all relevant parties need to make a concerted effort to fully integrate ICT knowledge and skills into the existing accounting curriculum. The accounting regulatory body, professional body, practitioners, and educators should adopt a suitable vision for the future and take on leadership roles in their respective areas. They should assess the current situation, develop a plan to solve problems and obstacles, and establish a monitoring program to encourage progress [29]. Advanced technologies, actively used in different fields in Society 5.0, aim to benefit all people, solving problems in their daily lives, without excluding any individual. Scientific and technological advancements must be promoted for the benefit of society, with a focus on people and the Society 5.0 paradigm: a super-intelligent society [14, 33, 34].

Pauluzzo et al. [35] conducted a study to bridge the gap between the knowledge requirements of professionals in the field and the content taught to accounting students. They proposed changes, improvements, and adjustments to accounting curricula and training courses, considering the significant trends that will continue to affect the professional accounting sector. Furthermore, despite the importance of ICT for the accounting profession, the high costs associated with acquiring and maintaining such a major ICT innovation limit its implementation in many developing countries [36].

From another perspective, in recent decades, public organisations have undergone significant changes related to digitalisation. They have directed their digital services towards different users, including individuals, groups of citizens, and companies [37]. This increased accessibility enhances transparency, promotes trust, and fosters accountability in this sector. Multiple stakeholders, including citizens and government officials, can easily review financial reports [2]. The emergence of "megatrends", such as reforms, electronic public administration, and digitalisation, has created a demand for qualified accountants in public administrations and has increased the need for direct information, education, and training. This has challenged the traditional skill set of public finance managers [35]. Saxena et al. [34] identified practical issues affecting the public education sector. They described how education providers can improve formal and non-formal training curricula to bridge the education/practice gap that undermines the ability of public servants to face the complexity of the current work environment.

Research into public sector accounting has attracted considerable interest [35, 38]. For example, Ahmad et al. [2] claimed that, like in any private organisation, AI systems in accounting can enhance transparency in financial reporting, thereby improving accountability in the public sector and, ultimately, reducing the risk of corruption. Automating data entry and processing with AI can significantly reduce human errors and inaccuracies and improve the credibility of government financial statements and confidence in public sector financial accounts.

It is also crucial that public sector accounting professionals understand the contextual elements to avoid delays and resistance in reforms. These contextual elements include power structures, communication channels, informal networks, and communication flows before disseminating reforms [39]. Pauluzzo et al. [35] revealed a lack of practical perspective in developing accounting skills for graduates and public servants. This gap needs to be filled to meet the practical requirements of the current public sector context. Adhikari et al. [39] showed that education, training, and awareness-raising of accountants and government administrators are essential for implementing accounting reforms in the public sector, specifically the IPSAS.

Sellami and Gafsi [40] highlight the importance of governments taking necessary actions to strengthen their public financial management mechanisms. They also stress the need to promote an effective and skills-based accounting education system that provides in-depth knowledge of IPSAS. In order to create a solid and ethical framework for greater compliance with accounting standards and better performance in the public sector, it is essential to consider the following: objectivity, comprehensibility and logical structure, conventional structure, clear and objective language, adherence to formatting guidelines, formal register, clear structure, balance, precise word choice, and grammatical correctness.

Hence, compliance with accounting standards in the public sector also poses new challenges for accountants. The adoption of IPSAS and the national standards based on them will bring changes to accounting processes in the public sector. In fact, Slama et al. [41] reinforce the relevance of a strategy to adapt local standards to the International Financial Reporting Standards (IFRS), despite the challenge of the considerable cost in terms of time and money. Another challenge is described by Liberato et al. [42], suggesting differences between restrictions and incentives in implementing accounting

standards between developed and developing countries. They demonstrate that constraints are identified in both developed and developing countries, such as the lack of accounting knowledge and skills and the limitations of software and information technologies. To face the future challenges posed by IPSAS and European public sector accounting standards (EPSAS), graduates and public servants need adequate knowledge of the public sector accounting context and the characteristics of international standards. It is important to address this gap in education to prepare for the changes ahead. However, current higher education programs do not give significant attention to IPSAS. Although the United Nations designated quality education as the fourth SDG, developing countries and countries with emerging economies still lack the impact of ICT in education and online learning using digital technology [43].

Accounting education in the public sector is essential for developing a skilled workforce capable of meeting the unique challenges of financial management in the public sector. This, in turn, supports the overall efficiency, transparency, and accountability of government financial operations and public administration. Ultimately, this benefits citizens and the community [35].

In summary, organisations can use existing AI insights to streamline processes and enhance capabilities. Expert systems represent the most advanced form of AI in accounting, allowing accountants to consult them on various topics [24].

3 Concluding Remarks

In recent years, AIS have played a crucial role in promoting quality in accounting education. They are not just a set of tools for recording financial transactions. AIS have become agents of change, influencing accounting as a discipline and, consequently, the accounting profession. Clear technical standards and guidelines are necessary for planning, executing, monitoring, and evaluating the accounting process. This should be done by qualified personnel and supported by new ICT and emerging and regenerative technologies. The accounting profession faces new challenges due to regulatory changes, evolving accounting standards, the globalisation and complexity of financial transactions, technological advances and digitalisation, and ethical and social responsibility challenges. It is necessary to update and adapt education and training systems to face these emerging challenges, with ICT being one such system. In the case of developing countries, it is crucial for governments and public managers to promote and develop attractive career systems for the exercise of functions and the lifelong learning system, especially in an era of constant transformation and evolution.

The integration of AI into accounting systems has been one of the major catalysts for change in information systems. It has revolutionised the way accountants do their jobs by enabling them to process large amounts of data quickly and accurately. For example, machine learning algorithms can analyse patterns in accounting data to identify anomalies and trends, allowing fraud and errors to be detected more efficiently. As well as improving the efficiency of accounting processes, the use of AI is creating new opportunities for accountants. This evolution of the profession is moving beyond the mere collection and recording of financial information, making AI a key strategic partner for organisations. Accountants will now be able to focus on higher value-added tasks

such as data analysis, the interpretation of results, and the provision of strategic advice to clients. However, this transformation does not come without challenges. It will require an updated and technology-enabled accounting education programme, as accountants will need technical skills in data analytics and artificial intelligence. One of the main challenges is ensuring the security and privacy of data, especially as AI systems handle sensitive information from organizations.

Currently, accountants are facing these challenges while taking advantage of the opportunities provided by the integration of AI into AIS. It is expected that accountants will become even more proficient in emerging technologies, such as blockchain and automation, and play an even more strategic role in organisational decision-making. Quality education in accounting must therefore keep pace with this evolution by equipping future accountants with the technical and analytical skills needed to succeed in an increasingly digitalised environment, including not only a solid foundation in traditional accounting, but also a deep understanding of how emerging technologies are shaping the field. In doing so, educational institutions can ensure that future accountants are well prepared to meet the challenges and seize the opportunities presented by the ever-changing accounting landscape.

The importance of ethics and responsibility in the use of these technologies should also be emphasised in accountancy education. As accountants deal with sensitive and confidential financial information, it is essential that they understand the risks and ethical implications of their decisions, especially in the context of technologies such as AI and blockchain, which can introduce new challenges in terms of privacy and security. Updating accounting education programmes to incorporate technological advances is therefore not only about imparting technical skills, but also about cultivating a deeper understanding of the role of technology in society and promoting ethical and responsible values in accounting practice. This is consistent with the goals of Society 5.0, which aims to use technology to promote human well-being and sustainability, rather than pursuing technological progress for its own sake.

This study contributes to Academia by providing a snapshot of the new challenges posed to the accounting profession due to the changes in AIS, namely through the advent of AI. It also contributes to raising awareness of the theme among government and public decision-makers, orders and other professional bodies, education and training institutions, and the general community. Governmental and public decision-makers, professional bodies, education and training institutions, and the community must work together to achieve educational quality while integrating new technological instruments.

Regarding the specific case of the public sector, it has undergone reforms that require qualified accountants capable of handling the new dynamics and complexities. These reforms include electronic public administration and digitalisation, which have challenged the traditional skills of public servants [35]. These considerations have practical relevance for public organisations involved in the implementation of public accounting, specifically international standards such as IPSAS. The study's insights can assist these organisations in addressing new challenges and opportunities that may arise during the implementation process. Liberato et al. [42] argue that informed decision making

enables public managers to make effective choices and address the challenges associated with transition processes, promoting a transparent and accountable public sector and increasing trust and accountability between government and society.

Finally, and similar to the work of Tetteh et al. [43], the study also contributes to the literature on accounting education in developing countries and emerging economies by presenting new evidence of differences in perceptions and gaps in teaching-learning processes.

In summary, educational institutions and bodies involved in the profession, such as companies, the State, professional associations, professional bodies, or the Government, must provide education that responds to the needs of industry and society. They must work together in harmony to promote learning that creates new skills for accounting students and career professionals. These entities should be encouraged to collaborate on various activities, motivating and supporting students in their professional development and promoting the growth of active, sociable professionals who contribute to the social well-being of Society 5.0.

This study is not without limitations. It should be emphasised that it is limited to a bibliographical analysis. Therefore, further research should analyse the sensitivity of educators, students, and employers to the impact of AIS on the quality of education, something which could complement the present study.

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Roadmapping Cybersecurity for IoT-Enabled Smart Environments

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Abstract. In the era of IoT-enabled smart environments, there is great potential for enhancing the environment's efficiency while promoting a better quality of life for its occupants. However, this potential comes with unprecedented cybersecurity challenges that demand effective protection for these ubiquitous interconnected systems and data in the face of evolving threats. This study has two primary objectives: firstly, to provide an overview of existing literature on cybersecurity in smart environments, and secondly, to create a conceptual roadmap for an IoT-enabled smart environment cybersecurity framework. Motivated by the potential and impactful negative consequences of cyber threats in such systems and environments, ranging from data breaches to system disruptions, this research proposes a four-stage roadmap methodology: i) Iterative Background Research, ii) Design Implications, iii) Prevention Strategies, and iv) Future Research Paths. The proposed roadmap recommends exploring Edge-AI for detecting threats, using blockchain for maintaining data integrity, designing security measures that prioritize human safety, and refining regulatory frameworks. This approach guides the implementation of robust cybersecurity measures, bridging the gap between IoT's potential and the critical need for cybersecurity, and offering valuable insights for practitioners, researchers, and policymakers working towards securing smart and cognitive environments.

Keywords: Cybersecurity · Framework · Internet-of-Things · IoT · Vulnerabilities · Smart environments · Cyber-Physical Systems · CPS

1 Introduction

IoT integration into smart environments is radically transforming resource management across sectors, promising efficiency enhancement and improved quality of life. However, this paradigm shift introduces critical cybersecurity challenges that require immediate attention to protect such systems and environments against potential breaches.

The integration of sensors, actuators, and embedded systems into Smart Environments (SE) introduces potential vulnerabilities. As we witness the swift integration of Internet-of-Things (IoT) technology into these environments, we face both an opportunity and a challenge. While IoT-based approaches within SE offer benefits such as

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resource efficiency, occupant comfort, and improved quality of life, their widespread adoption has also given rise to a critical cybersecurity concern, it is crucial to protect interconnected systems and data against evolving threats.

This research aims to address the potential consequences of cyber risks in SE and formulate a conceptual roadmap for a cybersecurity framework in IoT-enabled environments. It focuses on a literature overview of cybersecurity in SE aiming to enhance security measures against evolving cyber threats, leveraging established management platforms such as AWS IoT Core, Azure IoT Hub, and modern edge computing solutions like Google Cloud IoT Edge and Microsoft Azure IoT Edge. The framework acknowledges key components such as lightweight communication protocols (e.g., MQTT, CoAP) [1], OWASP IoT Project [2] and ISO/IEC 27001 standards [3].

This document is organized into five Sections. Section 1 emphasizes the importance of addressing IoT-related cybersecurity challenges in SE. Section 2 outlines the actions to be carried out throughout the study. Section 3 provides an overview of related work and research in the field, offering preliminary results to understand the current state of IoT cybersecurity and identify key areas for consideration. Section 4 presents the roadmap design for the cybersecurity framework. Finally, Sect. 5 summarizes the main outcomes.

2 Research Methodology

The study employs a methodology based on fundamental aspects to tackle the cybersecurity challenges that exist in IoT-enabled SE. Finished in early 2024, this research ensures relative coverage across the IEEE Xplore, ACM Digital Library, and Scopus databases. Employing a strategic manual key search and screening process, it identified key theories and significant studies on central themes. The methodology aims to provide a broad view of the topic's development, critically assessing methodologies, examining nuances, and revealing connections between different works.

Table 1 introduces the adopted methodology for the related works overview, starting from the definition of objectives up to synthesizing the main findings. Together, the results of this research will pave the way for the design of a conceptual roadmap for a cybersecurity framework specific to IoT-enabled SE, whose core challenges have been previously addressed.

Table 1. Research methodology

Stage	Description
Objectives	• *Identify emerging patterns, trends, and areas where existing cybersecurity frameworks may not meet the specific security demands of SE* • *Design a roadmap with potential directions or enhancements to address identified gaps and challenges in securing IoT-enabled environments*

(*continued*)

Table 1. (*continued*)

Stage	Description
Keywords	• *The following keywords were chosen to reflect the core themes and concepts of the paper subject:* • *Cybersecurity, framework, IoT, vulnerabilities, smart environments, Cyber-Physical Systems (CPS)*
Search Strategy	• *Manually employ and refine keywords in several combinations for searches across databases and journals (IEEE Xplore, ACM Digital Library and Scopus)*
Search Execution	• *Conduct manual keyword searches in the chosen databases* • *Refine search results manually based on their relevance to the CPS/IoT security topic, using filters and search operators*
Inclusion Criteria	• *Screen titles and abstracts – Include relevant articles focused on cybersecurity and smart environments, prioritizing those with a notable presence of IoT or CPS systems* • *Prioritize recent peer-reviewed articles (last 6 years) and recent conference papers*
Screening and refinement Process	• *Exclude duplicates and works not in English* • *Exclude non-peer-reviewed sources* • *Exclude those not relevant to the topic*
Findings Extraction	• *Identify key aspects within SE and extract data, namely on framework features, protocols, applications, case studies, and comparative analyses relevant to IoT cybersecurity*
Synthesize Findings	• *Categorize and organize information to highlight key aspects and focus areas of cybersecurity frameworks, emphasizing attributes, differences, commonalities, and strengths*

3 Related Works

Upon review of the selected works and analysis of the extracted findings, it became apparent that key aspects could be effectively organized into distinct categories, facilitating a clearer comprehension of the results and ideas. Consequently, we have structured our research endeavors around three primary topics: Cybersecurity Frameworks, Cybersecurity Challenges, and Raising Awareness. This division aims to streamline the investigation and enhance the depth of the insights into each topic.

3.1 SE Cybersecurity Frameworks.

The first topic concerns SE cybersecurity frameworks and comprises several essential studies, each offering distinct perspectives on SE-related cybersecurity in diverse contexts. First, Jhanjhi et al. [4] study cybersecurity challenges in Industry 4.0, focusing on potential cyber threats, consequences, and countermeasures within the four layers of the IIOT: sensing, network, data/service, and application. The sensing layer deals with physical devices and is vulnerable to tampering and Denial-of-Service (DoS). The network layer facilitates communication and faces threats like Man-in-the-Middle (MITM) and DoS attacks. The data layer handles data processing and storage and is targeted by malware, hijacking and insider threats. The application layer provides user interfaces and is susceptible to phishing, sniffing, code injection and DoS attacks. Their paper offers a framework for understanding the current state of cybersecurity threats and privacy issues in the industry and guiding future research in this area. Second, Chakrabarty et al. [5] present a smart framework for IoT-enabled environments that enhance consumer interaction while maintaining essential control and management functions. This framework named Liberated Object Location System (LOLS) is a hierarchical distributed system that manages smart devices and their digital twins (virtual replicas operating on behalf of physical devices or systems), facilitates decentralized storage for captured data, and provides an interface for consumers to interact with their data and devices. It offers robust security features such as public key cryptography and AES256 encryption, making it suitable for complex IoT ecosystems like smart homes, buildings, and cities. Third, Vakakis et al. [6] investigate cybersecurity threats in Smart-Home/Office environments of Small and Medium-sized Enterprises (SME) within Digital Innovation Hubs (DIHs). They introduce an adaptable cybersecurity framework tailored to each SME's evolving needs and are responsive to changing cyber threats. Preliminary results indicate its potential to enhance SME cybersecurity within DIHs.

3.2 SE Cybersecurity Challenges.

The second topic comprises influential works consolidating key insights and perspectives on SE cybersecurity challenges. Leander et al. [7] explore the cybersecurity challenges in large-scale IIoT systems, emphasizing the shift from automatic to autonomous control for efficient and affordable production. They use a flow-control loop as an example and apply a threat model based on the Microsoft STRIDE method - which stands for Spoofing, Tampering, Repudiation, Information disclosure, Denial of Service, and Elevation of privilege - to identify cybersecurity needs, evaluate existing solutions, and discuss future research directions. Aljaryan et al. [8] discuss modern factory technologies, prevalent cyberattacks like industrial espionage, and solutions for future factory security. They note the importance of data security, especially during the COVID-19 pandemic, which saw increased cyber threats in modern factories, and briefly touch upon cybersecurity challenges in large industrial IoT systems. Algarni et al. [9] reviews the security and privacy challenges posed by the widespread use of IoT in areas like smart cities, smart homes, and smart healthcare. They emphasize the need for better security measures to protect sensitive data from malicious hackers, highlighting ongoing challenges like malware and secure privacy management in IoT applications. Minoli et al. [10] discuss

the IoT's growing presence in industries like smart cities and smart buildings. They note the potential for IoT to address various needs in commercial spaces, including comfort and security, while highlighting challenges such as cybersecurity and standards.

3.3 Cybersecurity Raise Awareness

The last area centers around raising awareness on the SE cybersecurity topic and its significance. Here, Zhao et al. [11] propose visualization dashboards for smart buildings that offer both safety and SE cybersecurity status information for IoT devices. These user-friendly dashboards, designed through a user-centered approach, aim to increase awareness among non-expert users, including house managers and residents. And Jesus et al. [12] revisit cybersecurity in Building Automation Systems (BAS) and smart buildings from the perspective of stakeholders, identifying unclear ownership processes as a barrier to the sector's cybersecurity maturity.

3.4 Preliminary Results

Overall, researchers prioritize robust security protocols and standards for secure communication and data protection in IoT networks. Authentication methods, like digital certificates and biometrics, are explored for verifying IoT device legitimacy. Using tools like scanning and penetration testing, vulnerability assessment identifies and mitigates potential weaknesses. Machine Learning (ML) and Artificial Intelligence (AI) are applied for threat detection, detecting anomalies and breaches in IoT systems. Blockchain ensures tamper-proof transaction records and data integrity. Privacy preservation techniques protect user data while enabling valuable analysis. Active research covers security in edge computing, incident response, regulatory compliance, and the human element, contributing to a comprehensive understanding and improvement of SE-related cybersecurity in IoT-enabled environments.

Table 2. Key aspects in IoT-enabled smart environments

Topic	Key Aspects
SE Cybersecurity Frameworks	• Adaptable frameworks for Industry 4.0 [4] • A holistic approach incorporating standardized protocols. [4] • Tailored solutions in SE. [5] • Refinement of regulatory frameworks. [6] • Blockchain applications for data integrity. [9] • Balancing security and functionality. [11, 12] • Human-centric security design. [11, 12]

(*continued*)

Table 2. (*continued*)

Topic	Key Aspects
SE Cybersecurity challenges	• Identification of threats and privacy challenges in large-scale IIoT. [4, 7] • Exploration of Edge-AI/Edge-ML for threat detection. [8, 9] • Addressing the environment's complexity [9, 10] • Practical utility for tackling real-world challenges through specific scenarios. [6, 11, 12] • Unclear ownership processes as a barrier. [12] • Continuous and online monitoring for taking countermeasures. [4, 9]
SE Raising Awareness	• User-friendly dashboards for smart buildings. [11] • Emphasizing the importance of user-centric design. [11, 12] • Focusing on user role-based visualizations, prioritization of safety alerts, and continuous improvement. [11] • Cybersecurity literacy and awareness. [11, 12]

In this way, Table 2 presents the preliminary results within IoT-enabled SE across the three critical fronts: Cybersecurity Frameworks, Challenges, and Raising Awareness. Each table row captures crucial aspects within the designated domains and expands to all works studied, including off-topic ones if they reinforce these contexts, offering a detailed overview of the explored dimensions. In the Cybersecurity Frameworks theme, it underscores the necessity for frameworks that can adapt to the dynamic landscape of Industry 4.0, advocating for a comprehensive approach that integrates standardized protocols while maintaining a delicate balance between security and functionality. Additionally, it emphasizes the importance of infusing human-centric design principles into security frameworks to ensure alignment with user needs and preferences. Transitioning to Cybersecurity Challenges, it delves into the complexities of threat identification within large-scale IIoT deployments, underscoring the significance of proactive measures such as leveraging Edge-AI/Edge-ML for threat detection. It further highlights the need for continuous, real-time monitoring to effectively mitigate emerging risks, while simultaneously addressing the complexities inherent in the SE environment and clarifying ownership processes to streamline security protocols. Finally, within the scope of Raising Awareness, it defends the implementation of intuitive, user-friendly dashboards aimed at disseminating critical cybersecurity information to stakeholders. Furthermore, it highlights the importance of promoting cybersecurity literacy and awareness initiatives to empower users with the knowledge and skills needed to navigate the evolving landscape of SE cybersecurity effectively.

4 Framework Roadmap Design

The findings presented in Table 2 form the basis for defining the main phases of the SE-based cybersecurity roadmap. Through a detailed analysis of the identified attributes, commonalities, and other specificities within cybersecurity frameworks, key contributions were categorized into four phases addressing specific facets of cybersecurity, where

each comprises multiple focus areas. Thus, the proposed roadmap framework, illustrated in Fig. 1, demonstrates a strong reliance on established methodologies from related works, particularly in Phase 1, termed "Iterative Background Search", leveraging contributions from existing methodologies, such as other study reviews and continuous refinement of cybersecurity challenges, ensures that the framework is supported by the latest developments and grounded in practical considerations. By identifying specific scenarios or case studies, the framework can provide useful assistance to address real-world challenges. Phase 2, "Design Implications of IoT-enabled SE", navigates the complexities of IoT device interconnectivity by prioritizing tailored solutions that strike a balance between security and functionality, with a particular focus on human-centric design principles and operational optimization. Phase 3, "Prevention Strategies", advocates for a holistic cybersecurity approach encompassing standardized protocols, policies, and continuous monitoring, with an emphasis on promoting cybersecurity literacy and awareness among stakeholders through user-centric approaches and effective visualization techniques. Lastly, Phase 4, "Paths for Future Research", encourages ongoing exploration and innovation in cybersecurity within IoT-enabled SE, highlighting areas such as Edge-AI/Edge-ML for threat detection, blockchain applications for data integrity, human-centric security design, and the refinement of regulatory frameworks to ensure compliance and enhance security practices. Through these phases, the roadmap seeks to adapt alongside technological advancements and secure the future of SE by addressing evolving cybersecurity challenges and embracing innovative solutions.

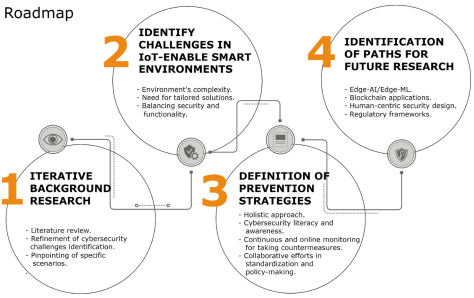

Fig. 1. Road mapping the design of a Cybersecurity Framework for IoT-enabled SE.

4.1 PHASE 1–Iterative Background Search

Focused on continuous improvement within cybersecurity frameworks, this iterative method ensures adaptability to evolving threats by recognizing their dynamic nature. Key contributions are outlined in Table 3 and include:

- **Literature review:** Conducting repeated research into emerging cybersecurity frameworks remains crucial throughout the process to address emerging threats.

- **Refinement of cybersecurity challenges identification:** Continuous identification of threats such as those found in large-scale IoT systems, allows for ongoing refinement and better understanding of the risks and vulnerabilities inherent to IoT-enabled SE.
- **Pinpointing specific scenarios:** The methodology emphasizes the importance of identifying specific scenarios or case studies from SE to showcase practical applicability in addressing real-world challenges.

4.2 PHASE 2–Design Implications of IoT-Enabled SE

In this phase, Table 4 illustrates the focus on human-centric design and operational optimization to ensure robust data security and enhance user experiences, including:

- **Environment's complexity:** Due to increased IoT device interconnectivity, security measures must address various attack vectors, including physical intrusions and technological espionage.
- **Need for tailored solutions:** Overcoming limitations of existing frameworks requires integrating human-centric design, operational optimization, secure data management, and economic stability, emphasized through examples or case studies.
- **Balancing security and functionality:** Essential strategies for maintaining security while preserving operational efficiency, such as phased implementation or user-centric design principles, would make recommendations easier to implement.

4.3 PHASE 3–Prevention Strategies

In response to escalating threats, this phase promotes a holistic cybersecurity strategy with standardized protocols, policies, and continuous monitoring. Collaboration in standardization and policymaking is highlighted for tackling interoperability, privacy, and data protection concerns. Emphasis is placed on promoting cybersecurity literacy and awareness, using user-centric approaches and effective visualization for enhanced preparedness. Table 5 outlines key contributions, including:

- **Holistic approach:** Is essential to establish a cybersecurity framework incorporating encryption, authentication, intrusion detection, and incident response for multi-layered defense. Providing case studies in SE is important to exemplify its application and effectiveness.
- **Cybersecurity literacy and awareness:** Promoting awareness among stakeholders and users is crucial and should be validated through successful campaigns or educational programs within IoT environments.
- **Continuous and online monitoring for taking countermeasures:** Implementing continuous monitoring and update mechanisms for IoT devices is crucial, along with examples showcasing the impact of prompt updates on mitigating vulnerabilities.
- **Collaborative efforts in standardization and policymaking:** Fostering collaboration among stakeholders, policymakers, and cybersecurity experts is essential, and should result in successful initiatives or frameworks to establish standards and share threat intelligence.

4.4 PHASE 4 – Paths for Future Research.

In the final phase of the roadmap, we encourage ongoing cybersecurity exploration and innovation in IoT-enabled SE. Table 6 lists the contributions for future research directions, guiding investigations to enhance security paradigms in IoT-enabled SE. This phase reflects the research's commitment to adapting alongside the technological landscape and securing the future of SE. Key focus areas include:

- **Edge-AI/Edge-ML:** Exploring Edge-AI for threat detection offers potential for real-time decision-making. By offering pilot studies demonstrating AI efficacy in mitigating threats within SE will underscore its potential.
- **Blockchain applications:** Studying the role of blockchain in ensuring data integrity and secure transactions in IoT environments is promising. Case studies demonstrating blockchain's success in SE would validate its applicability.
- **Human-centric security design:** Further research on user-centric security in IoT systems is critical. Presenting case studies showing how human-centric design improves security practices within SE would strengthen this recommendation.
- **Refinement of regulatory frameworks:** Developing regulatory frameworks specific to IoT-enabled SE is crucial for compliance. Examples showcasing robust regulatory frameworks enhancing security practices within SE would illustrate their effectiveness.

Table 3. PHASE 1 – Iterative background research

Focus Areas	Key Contributions	References
Literature review	*The continuous exploration of new cybersecurity frameworks is evident in studies like Jhanjhi et al., Chakrabarty et al., and Vakakis et al. These works contribute by presenting adaptable frameworks for Industry 4.0, IoT-enabled environments, and SMEs within Digital Innovation Hubs (DIH), respectively*	[4–6]
Refinement of cybersecurity challenges identification	*Several studies play pivotal roles in this area. For instance, Leander et al. focus on large-scale IIoT systems, applying the STRIDE method to identify cybersecurity needs. Aljaryan et al. also discuss cyber threats in modern factories with large-scale IIoT, emphasizing data security during pandemic scenarios such as COVID-19*	[7–10]

(*continued*)

Table 3. (*continued*)

Focus Areas	Key Contributions	References
Pinpointing of specific scenarios	*Numerous studies allude to the practical utility of tackling real-world challenges through specific scenarios and case studies within SE. Zhao et al. delve into comprehending usage contexts, handling cybersecurity and safety issues, customizing visualizations for distinct user groups, and iteratively enhancing design solutions based on scenario-specific needs and feedback. Meanwhile, Jesus et al. warn against the ramifications of unclear ownership in Building Automation Systems and Smart Buildings, hampering the sector's growth. The ideal solution involves a strategy with explicit ownership, defined roles, and robust controls for cybersecurity in smart buildings, addressing concerns such as unauthorized access, data breaches, and sensor manipulation. Vakakis et al. pinpoints the cybersecurity challenges in Smart-Homes/Office environments for SME's emphasizing the need for tailored solutions*	[6, 11, 12]

Table 4. PHASE 2 – Design implications of IoT-enabled SE

Focus Areas	Key Contributions	References
Environment's complexity	*Algarni et al. underscores the need to address security flaws during the design phase, emphasizing data privacy, confidentiality, and integrity. The security requirements outlined include robust authentication and authorization mechanisms and the use of security protocols like CoAP, MQTT, and TLS. Minoli et al. highlights IoT's impact on industries, focusing on device integration, user-centric design, and cybersecurity challenges. Examples like PoE and lighting applications illustrate the balance between simplifying integration and adapting to evolving standards, emphasizing the broader challenges of standardization and cybersecurity in IoT development*	[9, 10]
Need for tailored solutions	*Chakrabarty et al. and Vakakis et al. stand out in advocating for tailored solutions for IoT-enabled environments. The Chakrabarty smart framework, based on the Liberated Object Location System, prioritizes user-oriented and secure solutions*	[5, 6]
Balancing security and functionality	*Balancing security and functionality & Zhao et al. and Jesus et al. address the delicate balance between robust security measures and user experience. Zhao et al. highlight the crucial aspects of user role-based visualizations, prioritization of safety alerts, effective visualization techniques, and continuous improvement to achieve a balance between security and functionality in IoT-enabled SE, while Jesus et al. recognizes the integration of IT technologies for functionality improvement but notes a security lag*	[11, 12]

Table 5. PHASE 3 – Prevention strategies

Focus Areas	Key Contributions	References
Holistic approach	*Jhanjhi et al., Algarni et al., and Minoli et al. collectively contribute to a comprehensive cybersecurity approach. Jhanjhi concentrates on Industry 4.0 cybersecurity challenges, emphasizing strategies involving standardized protocols, policy frameworks, continuous monitoring, and collaborative efforts. Algarni reviews security and privacy issues in diverse IoT applications and points the direction into a combination of common security measures, continuous updates, edge computing solutions, blockchain technology, user awareness, government involvement, and ongoing research into evolving security approaches. And Minoli's overarching theme addresses standardization and IoT-cybersecurity challenges, advocating for a global strategy in the development of adaptive SE*	[4, 9, 10]
Cybersecurity literacy and awareness	*Zhao et al. and Jesus et al. are instrumental in promoting cybersecurity literacy and awareness. Zhao et al. emphasizes the importance of user-centric approaches and effective visualization in enhancing cybersecurity awareness and response capabilities in the context of IoT-enabled smart buildings, and Jesus et al. underscores the importance of increased awareness and literacy among stakeholders to enhance cybersecurity practices in this domain*	[11, 12]

(*continued*)

Table 5. (*continued*)

Focus Areas	Key Contributions	References
Continuous and online monitoring for taking countermeasures	*Jhanjhi et al. and Algarni et al. contribute to the significance of continuous monitoring to apply countermeasures and updates. Jhanjhi et al. advocate for adaptive monitoring systems across all layers of IIoT to swiftly detect vulnerabilities and evolving risks, supporting proactive risk mitigation and real-time threat detection, while Algarni et al. addresses measures that involve real-time incident response from edge devices, continuous application updates by companies, and the development of monitoring tools for IoT devices*	[4, 9]
Collaborative efforts in standardization and policymaking	*Algarni et al. and Aljaryan et al. underscore the critical role of collaborative efforts in standardization and policymaking for preventing security challenges in IoT-enabled SE. They emphasize the need for global standards, comprehensive frameworks, and government-led security solutions to address interoperability, privacy, and data protection concerns. The authors advocate a unified approach involving industry stakeholders, policymakers, and standardization bodies to establish a strong foundation for IoT security*	[8, 9]

Table 6. PHASE 4 – Paths for future research

Focus Areas	Key Contributions	References
Edge-AI/Edge-ML	*Algarni et al. and Aljaryan et al. offer insights into future research that tends towards Edge-AI/Edge-ML. Algarni highlights edge computing's potential in addressing security, privacy, and latency issues in IoT applications, enhancing system efficiency and resilience. Aljaryan et al. emphasizes key technologies such as cloud computing, IoT, big data, AI, 5G, additive manufacturing, and nanotechnology, underscoring AI and ML's crucial roles in real-time decision-making and control in smart factories and Industry 4.0*	[8, 9]
Blockchain applications	*Algarni et al. hint at the potential for blockchain in ensuring data integrity. This study reviews security and privacy challenges in various IoT applications, showcasing that blockchain's applicability should focus on scalability, efficient consensus mechanisms, vulnerability mitigation, and standardized protocols for secure communication*	[9]
Human-centric security design	*Zhao et al. and Jesus et al. highlight the importance of user-centric security design. Zhao et al. propose visualization dashboards for smart buildings, designed through a user-centered approach, while Jesus et al. points to unclear ownership processes as a barrier, suggesting further research on human-centric security design*	[11, 12]
Refinement of regulatory frameworks	*Vakakis et al. underpin in their work on SME's cybersecurity in DIH the importance of refining regulatory frameworks tailored for IoT-enabled SE, ensuring compliance and accountability. Focus areas include international collaboration, legal considerations, continuous monitoring, incentives for compliance, among others*	[6]

5 Conclusions

This research highlights the urgency of addressing cybersecurity challenges in IoT-enabled SE as they rapidly evolve. Successfully achieving its initial objectives, the study's roadmap provides a preliminary guide for implementing robust cybersecurity measures. It navigates into background research, design implications, prevention strategies, and future research paths, aligning with the dynamic nature of IoT security. Despite learning difficulties in the face of evolving threats, the research underscores the opportunities for adaptive planning. The global cybersecurity approach, integrating encryption, continuous monitoring, and user-centric design, emerged as a key lesson. The interdisciplinary nature of the study emphasizes the importance of merging expertise in IoT technology, cybersecurity, and domain-specific knowledge for effective solutions. The outlined paths for future research propose directions such as AI integration, blockchain applications, human-centric security design, and regulatory frameworks, fostering continuous innovation in this field. In essence, this research offers practical and applicable insights, providing a roadmap for practitioners, researchers, and policymakers to secure IoT-enabled SE. To consolidate this study, future work includes reviewing a significant number of references, identifying specific IoT security challenges and use cases for practical scenario evaluation, conducting a thorough analysis of potential threat vectors, exploring identified attack vectors to grasp real-world vulnerabilities, and formulating preventive and remediation strategies based on acquired insights. The lessons learned emphasize continual adaptation and collaboration for a resilient and secure IoT future.

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Artificial Intelligence and Education-a New Matter

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Abstract. When incorporating AI with Digital Information and Communication Technologies (DICTs) in the teaching-learning process, there are important obstacles that must be examined to guarantee high-quality, equitable, and inclusive education for everyone. Therefore, incorporating these emerging technologies into education is a challenge that requires careful thought.

By highlighting previous studies that allow/facilitate/promote the maturing of the subject in the certainty that this scenario is here to stay, we do not intend to exhaust the subject, but to put it into context.

This article presents a literature analysis on the topic of AI and DICTs in Education. The major objective is to emphasize the need for serious discussion among many educational stakeholders, including educators, students, educational institutions, governments, researchers, and institutional design developers.

Keywords: Artificial Intelligence · Education · Higher Education · ChatGPT · Ehics

1 Introduction

"Whether we welcome it or not, AI is increasingly being used widely across education and learning contexts. We can either leave it to others—the computer scientists, AI engineers and big tech companies—to decide how artificial intelligence in education unfolds, or we can engage in productive dialogue. It is up to each of us to decide whether we acquiesce, take what we are given, or whether we adopt a critical stance, to help ensure that the introduction of AI into education reaches its potential and has positive outcomes for all." [1, p.653]

As stated by Coppin [2, p.4] Artificial Intelligence (AI) refers to the capacity of machines to adjust to new circumstances, handle emerging situations, resolve problems, respond to inquiries, devise strategies, and perform other tasks that typically require human-like intelligence. However, although AI is a technology that enables machines

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to learn from data and make decisions like humans by inferring, reasoning, applying logical rules, and identifying patterns, it is important to acknowledge that the definition of AI is intricate. This is because it can encompass concepts such as consciousness, identity, and mind [3].

Artificial intelligence emerged initially as information technologies and computer technologies, progressing to web-based intelligent systems and e-learning. Embedded computer systems have evolved to incorporate humanoid robots and web-based chatbots, which are capable of autonomously or collaboratively performing supervisory roles and functions [4].

Education serves as the fundamental basis for an individual's life, fostering achievement, analytical reasoning, and strategic career development. It empowers individuals to cultivate their character, enhance their social aptitudes, and foster personal growth. Artificial Intelligence, when used to education, has the ability and capability to greatly enhance individualized learning, analyze vast quantities of data, and offer focused assistance to all individuals involved.

However, despite the considerable possibilities, there are several concerns that need to be considered.

2 Artificial Intelligence in Education: Contextualization

The implementation of Artificial Intelligence in Education (IAEd) is the outcome of a progressive process of technical advancement that has necessitated adjustments in pedagogy over the years and is still far from reaching its maximum potential. The use of Intelligent Adaptive Education has led to increased efficiency, global and individualized learning, intelligent content tailored to each student's profile, and improved efficacy and efficiency for educational administration [4]. Indeed, these authors have utilized the machine's learning power and flexibility to personalize the curricula and content based on the specific needs of the students. Their predictive ability, which relies on logarithms that can detect patterns and forecast student performance, has facilitated the identification of students who are at risk of dropping out early on. Additionally, it enables educational agents to offer tailored interventions to support academic advancement.

AIEd has transformed education and has been extensively studied and acknowledged by various authors. It offers several advantages, including personalized learning that tailors teaching systems to meet the unique needs and learning styles of students [5]. Additionally, it enhances the effectiveness and efficiency of education [6]. Artificial Intelligence provides educators with robust resources to assist them in designing, assessing, and providing constructive criticism for instructional sessions [7]. It can help reduce the administrative and routine responsibilities of teaching agents, allowing them to have more time for direct engagement with students and engaging in more innovative teaching activities [8]. Luckin et al. [9] emphasize the advantages in operational efficiency that educational institutions can gain by utilizing AI to manage resources, analyze data, and make more strategic decisions.

We are referring to what the authors such as Zawacki-Richter et al. [10] have classified as 4 primary domains of AI in Education together with 17 subcategories, as depicted in Fig. 1:

a) *Profiling and Prediction* refers to the utilization of artificial intelligence to evaluate the best suitable academic trajectory for a specific "profile," using data obtained from the profile itself;
b) *Intelligent Tutoring Systems* (ITS) utilize artificial intelligence (AI) to enhance teaching and learning by providing individualized instructional interventions. These are referred to as Intelligent Tutoring Systems, which, as Vanlehn [11] highlights, are systems with the ability to offer instructions and personalized feedback based on the individual's level of knowledge and learning style;
c) *Assessment and Evaluation* involves utilizing AI to automate and enhance aspects related to evaluating the educational process by implementing strong mechanisms for assessing teaching methodologies and effectiveness;
d) *Adaptive Systems and Personalization*, this domain focuses on utilizing artificial intelligence to tailor educational experiences to the specific needs of individual students.

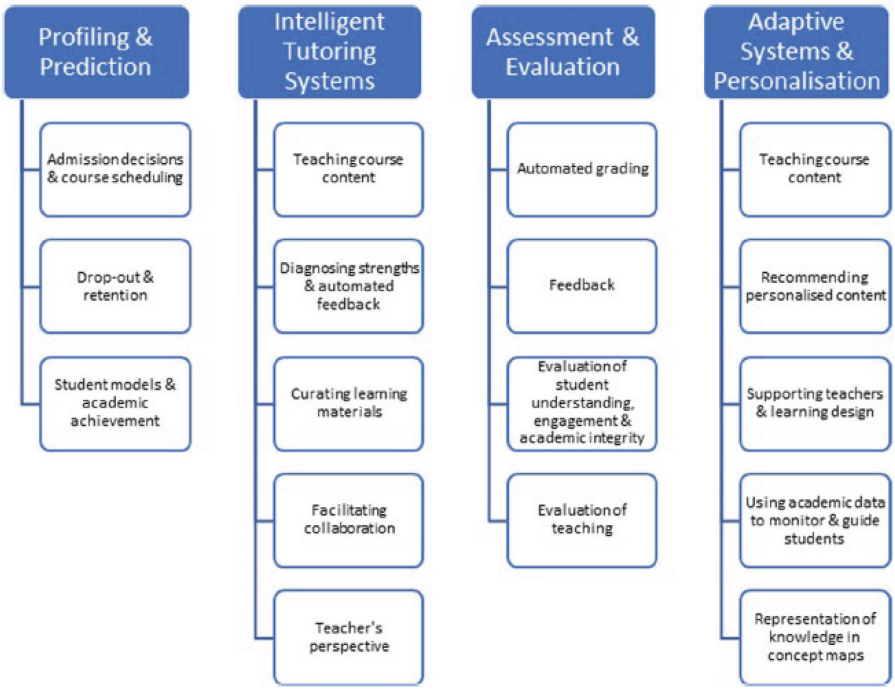

Fig. 1. Zawacki-Richter [10] original AIEdmTypology

Nevertheless, as noted by Kai-Fu Lee [12] "*AI cannot create, conceptualise, or manage complex strategic planning; AI cannot accomplish complex work that requires precise hand-eye coordination; AI cannot deal with unknown and unstructured spaces, especially ones that it hasn't observed; and cannot, AI unlike humans, feel or interact with empathy and compassion*"… tasks that can only be done by a human teacher, thus

we concur with his main argument there will still be a great need for human educators in the future.

2.1 The Challenges of AI in Education

It is imperative to recognize that incorporating AI with Digital Information and Communication Technologies (DICTs) for educational purposes presents significant challenges. Hence, it is imperative to conduct a comprehensive analysis and investigation of these matters in order to ensure education of exceptional standard, fairness, and inclusivity for all individuals.

Concerns regarding privacy, security, uneven access to technology resources [13], the ethical implications of AI in education, [1], transparency and explainability of the system [14], are significant challenges that must be acknowledged.

An ongoing challenge is to adequately educate and equip instructors to seamlessly incorporate AI into their teaching methods [15], particularly considering that most teachers are unfamiliar with this technology. Prior to Chiu [16] study in 2024, university officials and instructors had not encountered GenAI.

Chiu [16] asserts that the enabling mechanisms of AI enhance self-sufficiency and adaptability in learning. Chiu highlights that students exhibit a preference for AI applications, such as ChatGPT, since they perceive human-computer connection to be more effortless, hence diminishing the importance of interpersonal contact. However, the integration of AI and other technology in education necessarily results in a diminished level of human involvement during the teaching-learning process.

Interactions with teachers and peers are essential for students' cognitive and socio-emotional development, and artificial intelligence can limit or even replace these interactions. In addition, excessive use of technology can lead to a loss of social and interpersonal skills, such as effective communication and teamwork [17]. Chiu [16] cited Bowles and Kruger [18] and Bonfield et al. [19] to emphasize the significance of future classrooms in fostering crucial skills required for the job market. Specifically, interpersonal communication skills are identified as essential and will remain so in the digital era.

Moreover, despite its potential, a country can fall behind in both AI research and digital infrastructure [20] with technical, financial and literacy barriers [21], such as the high costs associated with developing virtual programming and high-speed internet [22].

Hence, it is crucial to find a middle ground between the potential advantages and the ethical, technical, and cultural limitations that AI will unavoidably impose on education. This will ensure that AI can play a constructive role in the advancement of educational systems.

2.2 Ethical Considerations

The literature has presented ethics as one of the great challenges of AIc.

The exponential growth of AI technology implementation in the field of education presents significant inquiries for stakeholders in the Information Technology (IT). Mindigulova et al.[23, p. 2000] emphasize several pertinent concerns, including:

- "what/whose values should be consistent with the introduction of AI systems (Gabriel. 2020;
- should there be any ethical norms for them in principle, or is their very essence incompatible with this concept?
- who should become the authors of these norms?
- and is it worth putting an equal sign between the moral principles of the authors of specific AI technologies and the norms of the "machines" themselves"

Mindigulova et al. [23] aim to address two inquiries: (1) how can AI assist individuals in the teaching and learning procedures during the present circumstances of online education; (2) what are the ethical values and standards that should be followed while utilizing AI technologies in the field of education?

As stated by Holmes et al. [1, p. 651] the ethical considerations concerning AI in education should include:

- "How does the transient nature of student goals, interests and emotions impact on the ethics of AIED?
- What are the AIED ethical obligations of private organisations (developers of AIEd products) and public authorities (schools and universities involved in AIED research)?
- How might schools, students, and teachers opt out from, or challenge, how they are represented in large datasets?
- What are the ethical implications of not being able to easily interrogate how".

It is crucial to acknowledge that the ethical considerations of AI in education must be thoroughly addressed. This is a complex undertaking that necessitates the participation of several stakeholders, including students, philosophers, teachers, policy-makers, parents, and AI advocates [1].

The subject of AI literacy requires thorough analysis and rigorous examination. Chiu [16] asserts that students, although they acknowledge and discern the advantages of AI, lack awareness of the potential hazards and vulnerabilities related to ethical issues, specifically privacy and the absence of transparency. It is important for teachers, policymakers, and learning scientists to comprehend the primary concerns brought up by data collecting and to effectively transmit this knowledge to students [1].

Issues such as the choice of which data to collect and which data to ignore, data ownership and data privacy are issues that need to be thought through and ensured. Furthermore, as Miller [24] points out in his study, we need to understand the computational approaches that are being applied: what decisions are being made, what biases are emerging and how can we ensure that the decisions are "*correct and transparent?"*.

Chu et al. [25] debate the ethical complexities associated with the delicate balance between human and machine-assisted learning, proposing that instructors should deliberately contemplate these concerns prior to integrating AI into their pedagogical approaches.

Educational organizations must not only provide society with what it needs now, but also anticipate the challenges that will arise in the future Cureton et al. [26]. Given their commitment and responsibility to society, higher education institutions are the spaces with the potential to discuss these issues without naivety and with the necessary critical spirit.

2.3 Need for Regulation

Universities have expressed ethical and moral concerns over the utilization of technologies that involve generative artificial intelligence. Concerns have emerged regarding disparities, intellectual theft, absence of analytical thinking, obstacles to creativity, and decline in knowledge acquisition.

One of the most recent AI-based advances is ChatGPT - a large language model (LLM) developed by OpenAI. It has been recognized as a groundbreaking breakthrough for gathering information. However, the challenges considered in the use of ChatGPT, in general, are commonly those pointed out in artificial intelligence technology itself: "*bias and prejudice, moderation of illegal or unethical content, privacy protection, fake news […]"* [22, p. 191].

When we view machine learning as the process of using data and algorithms to generate automated responses it brings about, new ethical challenges and the need to establish legal frameworks [27] hat safeguard both individuals and institutions, while also maintaining the necessary freedom for scientific advancement and rigor.

> *"ChatGPT and other comparable programs are functional prototypes that demonstrate the potential for teaching work. Students, teachers, and schools must be aware of and use this technology. To ignore these developments is to become captive to the actions of others, who will continue to invest in and develop these products (Baltar, 2023, p. 6).* [18, p.6]

Consequently, we assert that universities should take the initiative in fostering collaborations with governments, companies, and civil society organizations. This collective effort aims to establish suitable norms and regulations that will control the advancement and ethical utilization of artificial intelligence. Collaborations of this nature can contribute to the development of legislation that is grounded in a comprehensive comprehension of the ethical, societal, and economic ramifications of artificial intelligence.

Higher education institutions have a vital role in the training of professionals and the generation of knowledge. These centers have the capacity to serve as hubs for in-depth conversations and contemplation regarding ethical, social, and political matters pertaining to AI and other new technologies. This situation is ideal for debating the necessity of regulatory policy suggestions, as detailed in the studies conducted by [28]. In his book published by MIT Press in 2020, he emphasizes the importance of examining, developing, and scrutinizing AI policies.

3 Future Research Perspectives

According to Bond et al. [20] there is a dearth of research, absence of clear instructions, lack of established protocols, and absence of legal regulations to tackle the ethical issues that come from the utilization of AI in educational environments.

Although technology and AI are increasingly being used in education, it is important to thoroughly consider the potential effects on students, instructors, and society as a

whole [1]. This holds true for a wide range of topics, including accuracy, decision-making, forecasts, confidentiality, the role of educators, and the curriculum for students in schools and universities [29].

In order to cultivate trust and accountability, it is crucial to maintain a high level of openness and clarity in the field of education. In order to avoid blindly accepting the results, it is crucial for stakeholders to possess the ability to understand the mechanisms via which AI-powered systems produce recommendations or judgments [30]. In order to accomplish this, it is necessary to formulate innovative research questions.

> *"The state of AIHEd research within Education itself is an issue (Alam & Mohanty, 2022; Zawacki-Richter et al., 2019), and suggestions for more interdisciplinary approaches have been made, in order to improve pedagogical applications and out- comes (e.g., Kirubarajan et al., 2022). Potential further research approaches include:*

- Student perceptions of effectiveness and AI fairness (del Gobbo et al., 2023; Hamam, 2021; Otoo-Arthur & van Zyl, 2020);
- Combining student and educator perspectives (Rabelo et al., 2023;
- Low level foreign language learners and chatbots (Klímová & Ibna Seraj, 2023;
- Non formal education (Urdaneta-Ponte et al., 2021); and
- Investigating a similar dataset with data retrieved from different educational contexts (Fahd et al., 2022) [10, p.31-32]

Chiu [16] highlights the importance of conducting future research that focuses on the following areas: (1) The skills needed for the future workforce and the techniques used to assess them; (2) approaches that improve AI literacy and skills; (3) teaching methods that incorporate multiple disciplines; (4) innovative teaching approaches and their evaluation; and finally, (5) new assessment procedures and their acceptance.

Further investigation is necessary to examine the impact of personalization on emotional factors such as motivation, engagement, and interest [31], it is important for primary studies to give priority to offering comprehensive details about the methodologies and architecture employed. But as before, "*we consider it important that future research be planned and collaborated by multidisciplinary teams that analyze the issues raised from different perspectives"* [32, p.5].

For the sake of curiosity, we are sharing (Fig. 2) the feedback given by ChatGPT 3.5 to the prompted, "*using the literature identify potential gaps in research on AI and education"*.

Fig. 2. - Adapted from the Output provided from ChatGPT 3.5 at March 9th 2024

4 Conclusions

Artificial intelligence (AI) has emerged as a highly promising and effective technique. Allied to education, it allows instructors to tailor their teaching methods to the specific requirements and preferences of each student. In order to enhance the individualization of learning, artificial intelligence (AI) strives to customize educational experiences to align with the distinct requirements, preferences, and skills of every student [30, 33].

Given the ongoing impact of AI technologies on education, it is essential to carefully analyze and address the ethical implications and difficulties they provide. Ensuring the responsible and ethical use of AI in education and the future of society requires addressing concerns such as data privacy and security [33], educational bias/discrimination [34], transparency, student profiling, and equitable access.

To fully leverage the promise of AI while protecting the rights and well-being of all stakeholders, it is crucial to have strong data protection measures, unbiased algorithms, transparent decision-making procedures, and fair policies.

Although there has been notable advancement in AI education research, it is important to conduct additional studies and investigations to further improve ethical principles, adopt optimal methods, establish regulations, and monitor the lasting effects of AI on educational processes and results. To harness the full potential of AI in education, it is crucial to strike a balance between leveraging its transformational capabilities and addressing ethical concerns. This will enable us to design a future in education that is customized, fair, and has a significant impact.

Presently, the primary concern or obstacle in research is not the identification of voids in literature, but rather the integration of artificial intelligence into the scientific method. Implementing AI in a manner that ensures the timely utility of research outcomes. The key challenge in educational information architecture (IA) research is not only in identifying the areas of investigation, but primarily in devising successful strategies for incorporating IA into the research process.

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Drivers of Brand Love and Brand Loyalty in a Technological Context the Sony PlayStation

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Abstract. The increasingly easier way to communicate and interact in online brand communities makes consumers quickly change their opinion toward brands. In the specific case of the gaming world, consumers often look for the brand/product that their acquaintances use so that they can enjoy the same game at the same time (in the case of Sony, you can only play online with people who have the same type of console). The choice of the theme has to do with trying to understand how the gamer consumer builds brand loyalty. In this case, the chosen brand was Sony with the PlayStation product because it is in high demand and a brand many people identify with. In this way, brand satisfaction, brand identification, and brand image will be considered antecedents of brand love. In turn, brand satisfaction and brand love will be mediating variables between the variables of brand identification and brand image, and the final variable brand loyalty.

Keywords: Brand Love · Brand Loyalty · Technological Context · Sony PlayStation

1 Introduction

Brand loyalty has been widely investigated, not only because it is a very important issue in companies' marketing strategies, but also because customers have become more volatile and have reasons to be less loyal. Before defining any strategy, companies must know their customers well, their preferences, and how they can serve them better for a long-term relationship.

In marketing, one of the evolving areas of interest is brand love. Today, companies have recognized that feeling love toward a brand is vital in establishing a good relationship with a customer. Those brands that can make customers love their brands are more successful in gaining a sustainable advantage and beating their competitors [1].

Literature also distinguishes brand love from other similar and close concepts. For example, brand love is distinct from satisfaction. While satisfaction is a more cognitive and rational judgement, brand love is more affective. Moreover, brand love implies a long-term relationship, while satisfaction is a transactional-related outcome [2]. Brand love goes beyond brand affect because it is more profound and enduring [3]. Thus, brand love is not only more intense than liking, but also conceptually different. A beloved brand

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is part of a consumer's identity, since through its image and attributes, the consumer can express his/her own self [4]. Brand love has gained considerable importance in literature since it was first discussed by Carroll and Ahuvia in 2006 [2].

However, with the new role of consumers as co-owners and co-creators of the brand, the emphasis has shifted, and brands have begun to focus on a more relational perspective, where the value of a brand is the result of increased engagement with the customer. As such, the antecedents of loyalty now encompass new concepts such as brand love and brand identification. Brand satisfaction and brand image remain key determinants of brand loyalty. Thus, we will consider brand identification and brand image as determinants of brand love and brand satisfaction. In turn, brand satisfaction will influence brand love. Finally, brand satisfaction and brand love will be determinants of brand loyalty.

2 Theoretical Framework and Research Hypotheses

This section presents the theoretical framework that supports constructing our research model, whose final variable is loyalty to the Sony PlayStation games brand. We propose a model in which brand satisfaction and brand love are total mediating variables between the independent variables, brand image and brand identification, and the final variable, brand loyalty.

Loyalty involves "a deeply held commitment to rebuy or re-patronize a preferred product/service consistently in the future, thereby causing repetitive same-brand or same brand-set purchasing, despite situational influences and marketing efforts having the potential to cause switching behavior" [5, p. 34]. Thus, brand loyalty contributes to the repeated purchase of a brand to which the customer is loyal. Brand loyalty is critical because a slight increase in the number of faithful customers will have a positive effect on profitability [6]. In a more general classification, loyalty is divided into two aspects: attitudinal and behavioral loyalty, where the attitudinal dimension consists of three aspects: cognitive, affective, and conative. Thus, the literature emphasizes two aspects of brand loyalty: attitudinal and behavioral loyalty [5]. Specifically, attitudinal loyalty is defined as the degree to which an individual commits to the brand, and behavioral loyalty refers to the willingness to repurchase the same brand [76].

Brand satisfaction and love were considered essential as direct antecedents of brand loyalty. Already, brand identification and brand image with the brand were understood as indirect variables of brand loyalty via brand satisfaction and brand love.

Customer satisfaction has been an indispensable marketing concept [7, 8]. Customer satisfaction has been at the heart of marketing for a relatively long time because of its central status for the survival of a business [9]. Satisfaction refers to an emotional state resulting from a consumer evaluation of a service provided by a company and his/her response to it [10]. Kotler and Keller (2009) said that customer satisfaction is a person's feeling of pleasure or disappointment about whether the perception of the product performance matches expectations [11]. Many other studies support this latter definition, for example, Oliver (1980) [12]. Others define customer satisfaction as the feeling or attitude of customers toward a product/service after it has been used [13].

There are two ways to measure satisfaction: the first is based on specific transactions, and the second is based on overall satisfaction [14]. Transaction-specific satisfaction

is explained as customer evaluation of the consumption experience and the response regarding specific product transactions, episodes, or service encounters [15]. Overall satisfaction is the customer evaluation of a product or service provider [15, 16]. Previous studies argue that brand satisfaction is a precursor of brand love, but not all satisfied customers must love the brand [17].

Brand love is a more recent marketing construct, which has been shown to influence essential marketing variables such as brand loyalty and word-of-mouth. [35]. The concept of brand love is rooted in the theories of interpersonal love. The one that is most often cited is Stenberg's triangular theory of love (1986) [18], which has been presented as a highly correlated tri-dimensional concept that entails passion, intimacy, and commitment, it combines cognitive, emotional, and behavioral components, as Batra et al. (2012) suggested [19]. Love is a constellation of behavior, cognition, and emotions associated with a desire to enter or maintain a close relationship with a specific person [20]. Consequently, many researchers have defined brand love as a feeling for a brand similar to interpersonal love [21, 22].

The birth of the academic brand love literature is often associated with short conceptual paper by Shimp and Madden (1988) [23], as well as comment made by an interview respondent about her "real brand love" for coffee in an influential branding article by Fournier and Yao (1997) [24, p.465]. Despite these occasional flirtations with this idea, the term "brand love" did not become widespread among academics until the publication of Carroll and Ahuvia (2006) [21]. Shimp and Madden (1988) propose a conceptual model of "consumer–object relationships" inspired by the triangular theory of love (Sternberg, 1986), in which Sternberg's three components of love (intimacy, passion, and decision/commitment) become liking, yearning, and decision/commitment in a consumption context. When these three components exist, they strongly contribute to loyalty toward the object.

Early research on (what would later be called) brand love [22, 25–28] drew from psychological research on both interpersonal love [20] and consumer research regarding the role of favorite possessions in identity construction and interpersonal connections [29–31]. Ahuvia (2005) [27] particularly stressed the importance of loved objects in constructing consumer identity. This finding has recently been supported in a meta-analysis of neuroscience studies comparing brand love to interpersonal love. According to Carroll and Ahuvia (2006), brand love is defined as "the degree of passionate emotional attachment a satisfied consumer has for a particular trade name" [21, p. 81]. This stream of research has investigated brand love without referring to an interpersonal theory of love and propose instead that brand love consists of five characteristics: (1) passion for the brand, (2) attachment for the brand, (3) positive evaluation of the brand, (4) positive emotions in response to the brand and (5) declaration of love for the brand. However, their measurement of brand love is unidimensional and may fail to catch the complexity of love, a construct usually presented as multidimensional [19, 34]. Therefore, Carroll and Ahuvia (2006) [21] conceptualize brand love as a single-dimensional construct that refers to one's passionate emotional attachment to a brand.

Robert (2005)'s book "Lovemarks" provided in-depth information about brand love. According to the author of the Lovemarks book, brand love expresses the strongest emotional bond between the brand and the customer [36]. After Carroll and Ahuvia

(2006), two major studies further explored and defined the content of brand love. The first significant study was Albert, Merunka, and Valette-Florence (2008), who identified eleven dimensions of brand love: passion, duration of the relationship, self-congruity, dreams, memories, pleasure, attraction, uniqueness, beauty, trust, declaration of affect [22]. The subsequent major study was Batra, Ahuvia and Bagozzi (2012). Based on grounded theory, the authors identified seven core elements of brand love: (1) self-brand integration, (2) passion-driven behaviors, (3) positive emotional connection, (4) long-term relationship, (5) positive overall attitude valence, (6) attitude certainty and confidence, and (7) anticipated separation distress [19]. Therefore, after Carrol and Ahuvia (2006), other authors [19, 32] have built on this early research to create and refine a measure of brand love that encompasses a wide variety of dimensions including, self-brand integration, passion-driven behaviors, positive attitudes, anticipated separation distress, long-term relationship focus and positive emotional connection [33].

Brand Love is distinct from brand image [21]. Brand image is a perception about brands reflected by brand associations held in consumers' memory [37]. These associations are formed due to product attributes and benefits received from the products, and not necessarily an outcome of relational exchanges. 'Brand love' is a form of emotional connection formed over time, comprising cognitive and affective aspects [2, 19]. Brand love may be seen as what we commonly call "fanaticism" for a brand, where consumers are so affected by this love that they will stop consuming what other brands can offer [38].

Brand image has been considered an important construct in marketing since the 1950s [42]. The concept of brand image has evolved over time. Early marketing scholars [39] mainly emphasized the cognition-focused dimension of brand image. These scholars described brand image as the totality of the impressions of attributes, functions, and meanings that consumers associate with a brand. More recently, marketing scholars [40] have recognized that emotional and sensory associations are important in building a positive brand image [41].

Brand image is defined as a consumer's mental picture of a brand that includes symbolic, functional, and reasoned brand beliefs [40, 43] and helps differentiate a brand [44]. According to self-concept theory, a stronger emotional bond is created when congruence between brands and consumers' self-image is established [43–45]. Brand-image literature also suggests that customers may assign human attributes to the brands they use [28, 44], leading them to love the brands as an emotional end result [43]. Brand image is based on consumer impressions of a particular brand [46]. These views are kept in the consumer's memory as a network of connections. These can be converted into three crucial brand image characteristics: the favorability, strength, and uniqueness of brand associations.

Brand image is society's perception of the company or its products [47]. Brand image can be considered a type of association that arises in the minds of consumers when remembering a particular brand. The association can appear in the form of specific thoughts or images associated with certain brands. It's the same when we think about other people. Brand image gives consumers a guarantee about the products used. Well-known brands will generally be preferred by consumers when purchasing, even though the price is quite high. Brand image represents the overall perception of the brand and

is formed from information and past experiences of the brand. The brand formed must be clear and have advantages compared to other brands [48]. The brand image reflects consumers' feelings about a specific brand, which arise from consumers' knowledge and memory of a brand [50].

Brand identification is essential in building a strong and favorable relationship between consumers and brands [49]. Brand identification is drawn from consumer–company identification [52] and social identity theory [53]. Social identity theory states that individuals tend to enhance their self-identity and self-esteem by identifying with a specific social group [54]. Consumer–company identification is conceptualized as 'an active, selective and vocational act motivated by the satisfaction of one or more self-definitional needs' [53, p. 77]. Like social groups, organizations and other objects, brands, as carriers of symbolic meanings may facilitate individuals to accomplish their self-identity needs and goals [55]. Consistent with organizational identification literature, brand identification is conceptualized as a consumer's perceived state of oneness with a brand [52, p. 407] that helps in identity-fulfilling meaning through brands [56]. Social identity theory (SIT) is an essential theoretical foundation for marketing-based customer brand identification. SIT advocates that people will expend significant effort to develop their own social identity and their more private identity [52, 54].

Consumers choose products and brands not only for their utilitarian values but also for their symbolic benefits. Brands possess deep meaning and serve to build consumers' self-concept or identities [58]. Consumers use brands to construct, present themselves to others, or achieve their identity goals [59]. Brand identification has been emphasized as identification fulfils the need for social identity and self-identification [58].

Various authors suggested that customers with higher identification levels are more likely to be satisfied with the firm [50, 60, 61]. Consequently, the following hypothesis is proposed:

H_1: Brand identification has a positive impact on brand satisfaction.

In the literature, it has been widely acknowledged that brand image affects brand satisfaction. Several studies have empirically examined the link between brand image and other marketing constructs. These studies showed that brand image positively affects customer satisfaction and brand satisfaction. It is essential to understand the process of image formation and how it relates to satisfaction by analysing the impact of brand image on consumer satisfaction. In recent years, many works have demonstrated the influence of brand image on brand satisfaction [50, 62–66, 90]. Accordingly, the following hypothesis is posited:

H_2: Brand image has a positive impact on brand satisfaction.

A consumer who identifies with a brand develops positive feelings toward it [67]. Ahuvia (1993) also notes that an object or brand must be perceived as part of the consumer to be loved, such that loved objects express deeply held values and highlight the consumer's identification with the brand [26]. As such, a consumer who identifies with a brand develops positive feelings toward it. Love for a brand should grow if the brand plays a vital role in a consumer's identity construction [3]. Brand identification is essential in building a strong and favorable relationship between consumers and brands.

Many studies demonstrated that brand identification determines brand love [47, 68–70, 91]. In this way, we propose the following hypothesis:

H_3: Brand identification has a positive impact on brand love.

Recently, numerous studies have shown that a company's brand image can influence how much people love its products or services [17, 21, 36, 47, 62, 64]. Consequently, we expect that brand image affects brand love:

H_4: Brand image has a positive impact on brand love.

Some researchers also advocate the relationship between brand satisfaction and brand love, proposing that when the consumer feels satisfied with consuming a brand more than once, this experience will most likely create a love relationship with the brand in question [76]. Most current studies have found evidence of the effect of customer satisfaction on brand love [50, 64, 71, 72, 75] because higher satisfaction leads to brand love. Thus, we hypothesized the following:

H_5: Brand satisfaction has a positive impact on brand love.

Previous empirical studies argued that satisfied clients are more likely to be loyal. Many studies confirm this relationship [61, 63, 65, 71, 73, 74]. Therefore, we hypothesized the following:

H_6: Brand satisfaction has a positive impact on brand loyalty.

Previous studies have stressed that brand love is positively related to brand loyalty, an outcome appropriate for the company and the brand [2, 9, 35]. Consumers' love towards brands has a significant positive effect on brand loyalty [38, 47, 50, 57, 61, 63, 71, 73, 77, 78]. Consequently, the following hypothesis is proposed:

H_7: Brand love has a positive impact on brand loyalty.

3 Research Methodology

The research model, presented in Fig. 1, proposes that brand identification and image influence brand satisfaction and love. In turn, brand satisfaction influences brand love. Finally, brand satisfaction and love positively impact brand loyalty.

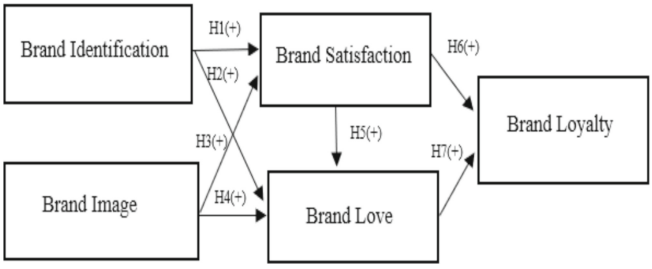


Fig. 1. Proposed conceptual model

3.1 Sample Selection and Data Collection

This research study used a structured and self-administered questionnaire that addressed all the information needed. A sample of convenient elements was obtained by using a non-probabilistic convenience sample. Data was collected through an online survey, and 236 valid responses were received. As for the gender of the respondents, we obtained 41 female and 195 male responses, which represent a percentage of 17.4% and 82.6%, respectively. The age of the respondents was 64.4%, and the sample was between 18 and 30 years old. Finally, 11.8% had completed high school and 37.7% held a university degree.

3.2 Measurement Scales

The constructs' measurement scales were based on literature. All variables were measured on a seven-point Likert scale, ranging from 1—strongly disagree to 7—strongly agree (Table 1).

Table 1. Variable scales

Variables	Scales used
Brand Image	[85]
Brand Identification	[84]
Brand Satisfaction	[82]
Brand Love	[83}
Brand Loyalty	[2, 80, 81]

4 Analysis and Results

4.1 Measurement Model

An initial screening of each scale was conducted using item-total correlations and exploratory factor analysis (EFA) using SPSS 29.0. Following Anderson and Gerbing's (1988) [85] two-step approach, a measurement model was estimated before testing the hypotheses, using a structural model. The data was analyzed through confirmatory factor analysis (CFA) and structural equation modeling (SEM) using the statistical software AMOS (Analysis of Moment Structures) version 29.0. Maximum likelihood estimation procedures were used since these afford more security in samples that might not present multivariate normality.

The measurement model fits the data well ($X2 = 287.789$, $df = 94$, $p < 0.001$; $X2/df = 3.062$; $IFI = 0.97$; $TLI = 0.96$; $CFI = 0.97$; $RMSEA = 0.094$).

CFA enables the performance of tests regarding convergent validity, discriminant validity, and reliability of the study constructs. A commonly used method for estimating convergent validity examines the factor loadings of the measured variables [85]. Factor loadings greater than 0.5 are considered very significant [86]. Also, we used the AVE to contrast convergent validity. Fornell and Larcker (1981) suggested that adequately convergent valid measures should contain less than 50% error variance (AVE should be

0.5 or above) [87]. Convergent validity was achieved in this study because all the factor loadings exceeded 0.5 and all AVEs were greater than 0.5. Next, CFA was used to assess discriminant validity. If the AVE is larger than the squared correlation between any two constructs, the discriminant validity of the constructs is supported [87].

The composite reliability (CR) for each construct was generated from the CFA to assess reliability. The CR of each scale must exceed 0.7 thresholds [88]. As Table 2 shows, all the constructs' composite reliability coefficients are excellent, being larger than 0.9, except for the variable brand image (0.89). Cronbach's alpha indicator was also used to assess the initial reliability of the scales, considering a minimum value of 0.7 [89]. As shown in Table 2, coefficient alpha values are all over 0.9, exhibiting high reliability, except for the variable brand image (0.89). Table 2 also shows the AVE for each construct, and a correlation matrix of constructs is also shown. In Table 3, we can see the standardized loadings and t-values of all scale items.

Table 2. Factor Correlation matrix and measurement information.

Construct	CR	AVE	X_1	X_2	X_3	X_4	X_5
Brand Identification (X_1)	.97	.92	*.97*				
Brand Image (X_2)	.89	.73	.63	*.89*			
Brand Satisfaction (X_3)	.98	.94	.60	.83	*.98*		
Brand Love (X_4)	.96	.87	.77	.83	.87	*.96*	
Brand Loyalty (X_5)	.96	.89	.72	.81	.85	.86	*.96*

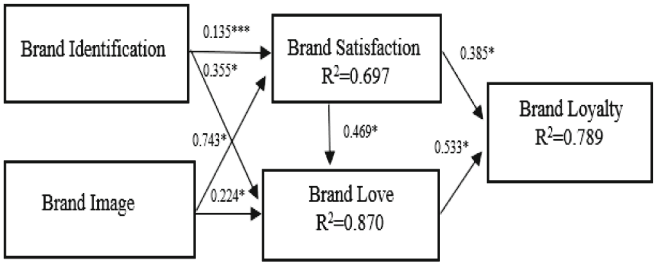
Note: In diagonal entries (italic) are Cronbach's alpha coefficients; AVE, average variance extracted; CR, composite reliability.

Table 3. Measures, standardized parameter estimate results and measurement model t values

Measures	Standardized Loadings	t-Value
Brand Identification		
BIDEN1	0.937	19.098
BIDEN2	0.970	20.336
BIDET3	0.966	20.186
Brand Image		
BIMAG1	0.816	14.895
BIMAG2	0.924	18.147
BIMAG3	0.812	14.779
Brand Satisfaction		
BSATIS1	0.976	20.642
BSATIS2	0.971	20.448
BSATIS3	0.963	20.114
Brand Love		
BLOVE1	0.866	16.697
BLOVE2	0.962	20.057
BLOVE3	0.950	19.574
BLOVE4	0.945	19.405
Brand Loyalty		
BLOYA1	0.927	18.714
BLOYA2	0.915	18.286
BLOYA3	0.983	20.838

4.2 Structural Model

The structural model, depicted in Fig. 2, fits the data well (X2 = 309.539, df = 96, p < 0.001; X2/df = 3.224; IFI = 0.96; TLI = 0.95; CFI = 0.96; RMSEA = 0.097).



R^2=squared multiple correlations; *p<0.001; ** p<0.01; ***p<0.05.

Fig. 2. Structural model

The results in Table 4 show that all seven hypotheses proposed in the structural model were supported.

Table 4. Estimation results of the structural model

Path	Standardized coefficient	t-Value	Hypothesis
Brand Identification→Brand Satisfaction	0.135***	2.436	H1 (+): S
Brand Image→Brand Satisfaction	0.743*	11.175	H2 (+): S
Brand Identification →Brand Love	0.355*	9.245	H3 (+): S
Brand Image→ Brand Love	0.224*	3.666	H4 (+): S
Brand Satisfaction → Brand Love	0.469*	8.278	H5 (+): S
Brand Love →Brand Loyalty	0.533*	7.290	H6 (+): S
Brand Satisfaction→Brand Loyalty	0.385*	5.371	H7 (+): S

Note: * p<0.001; ** p<0.01; *** p<0.05 (one-tail tests).

The variable that exerts a more substantial impact on brand satisfaction is brand image, and brand identification influences brand love more strongly. In other words, being brand love is a more emotional variable, brand identification stands out as its determinant. Previous studies found that overall brand identification strongly influenced brand love [2, 3]. On the other hand, brand image is evidenced as an antecedent of satisfaction with the brand. However, brand image and brand identification influence brand satisfaction and brand love. In turn, brand satisfaction is a significant determinant of brand love. Finally, although brand satisfaction and brand love are fundamental antecedents of brand loyalty, brand love stands out. The brand under analysis is an emotional brand by nature, i.e., its customers attribute to it beyond a utilitarian value, an emotional value. Once brand love reflects positive, passionate relationships with brands [2, 19], it is distinct from mere liking and involves a higher affective component than satisfaction [2]. Thus, brand love might influence brand loyalty more than satisfaction. However, brand satisfaction has also demonstrated a positive influence on brand loyalty.

However, the analysis of the total effects, direct and indirect, becomes very important, since the analysis of the direct effects may not be revealing. As shown in Table 5, the Boostrapping technique was used with a sample of 2,000 random observations generated from the original sample and a 95% confidence interval.

Table 5. Standardized direct, indirect and total effects

Paths	Direct effects	Indirect effects	Total effects
Brand Identificatio —>Brand Satisfaction	0.135****	-	0.135****
Brand Image—> Brand Satisfaction	0.743*	-	0.743*
Brand Identification —>Brand Love	0.355*	0.063****	0.418*
Brand Image —>Brand Love	0.224***	0.348*	0.572*
Brand Satisfaction—>Brand Love	0.469**	-	0.469**
Brand Identification —> Brand Loyalty	-	0.275*	0.275*
Brand Image—> Brand Loyalty	-	0.592*	0.592*
Brand Satisfaction—> Brand Loyalty	0.385*	0.250*	0.635*
Brand Love—> Brand Loyalty	0.533*	-	0.533*

Note: * p≤0.001; ** p≤0.01; *** p≤0.05; p≤0.1****.

Considering the total effects (direct and indirect), the variable that had the most substantial total effect on brand love was brand image because of the indirect effect, via brand satisfaction. On the other hand, brand identification has a stronger direct effect on brand love but has a weaker total effect than brand image.

The variable with the most substantial total effect (direct and indirect) on brand loyalty was brand satisfaction, followed by brand image and brand love. Brand identification, on the other hand, had a weaker total effect, although significant. That is, through its direct impact on brand satisfaction and brand love, brand image had a powerful indirect effect on loyalty. On the other hand, brand identification had a weaker indirect impact on loyalty. In turn, the direct effect of brand satisfaction on brand loyalty, associated with the indirect effect, via brand love, was the most substantial total effect.

5 Analysis and Results

In gaming, using the PlayStation brand, brand satisfaction and brand love are key to achieving brand loyalty. In recent studies [61, 63, 71, 73], brand satisfaction and brand love are essential to reach Sony PlayStation brand loyalty. Brand image and brand identification are important determinants of brand satisfaction, as in recent studies [63–66]. Brand image [21, 36, 64] and brand identification are drivers of brand love [69, 70]. Brand satisfaction is a strong antecedent of brand loyalty [64, 71, 75]. It should be stressed that the image of this brand is also essential to gain brand loyalty, via brand satisfaction and brand love, as it has a powerful image. Brand identification, if, however, has a minor impact on brand loyalty, via brand satisfaction and love, is also crucial to foster loyalty. Thus, managers should be aware of the importance of PlayStation Sony customers identifying with the brand, having a favorable brand image, and being satisfied with and loving the brand.

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Brand Engagement in Achieving Customer Satisfaction and Brand Loyalty for Sony's Gaming

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Abstract. In PC gaming, it is paramount that players have an enjoyable experience with their favourite brand and feel involved so that they become engaged, satisfied, and loyal to the Sony console brand. The choice of the theme has to do with trying to understand how the gamer consumer builds Sony brand loyalty. This research proposes a theoretical model that is tested through structural equation models. For this purpose, an online questionnaire was posted on Facebook brand communities, and 246 valid questionnaires were collected. The results demonstrate that brand experience and involvement are key variables in engaging gamers with the Sony brand. In turn, when players are engaged with the Sony brand, they are satisfied and become loyal to the Sony brand. Finally, satisfied gamers develop loyalty to the Sony brand.

Keywords: Brand Involvement · Brand Engagement · Brand Satisfaction · Brand Loyalty · Sony PlayStation

1 Introduction

Brand loyalty is a widely studied concept in marketing [1]. In today's increasingly competitive marketplace characterized by fickle consumers, patronage intent is fundamental [2]. Loyalty is a customer's intention to say positive things about a brand to other people and declare to purchase this brand in the future [3].

In marketing, brand involvement and engagement are evolving areas of interest. Customers involved and engaged with a brand are more satisfied and loyal. Brand experience is another strong antecedent of satisfaction and loyalty to a brand. In today's market scenario, characterized by technological developments and social media [4], firms have the opportunity to connect with their customers outside the purchasing context in offline stores (e.g., through blogging or online communities), and customers can easily interact with other customers outside the service consumption [5]. In this scenario, customers can contribute to brands/ firms, not only in the form of purchases, but also by referring the brand to other customers or talking about the brand/ firm on social media or even giving suggestions and feedback about the company's goods/services [6]. This

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new marketing era has emphasized the need for firms to keep their customers engaged [4].

With time, managers and academics have realized that satisfaction is no longer enough to ensure loyal and profitable customers. Therefore, the goal of organizations evolved from relationship marketing to engaging in all possible ways [7]. Engagement, as a new concept, is regarded as a complex topic due to the high number of publications in recent years about customer engagement, the lack of consensus on the conceptualizations and scales to measure the construct, the different contexts where the concept is applied, and the different actors involved. Therefore, a holistic understanding of the phenomenon will enable the identification of future research areas [97].

The literature also distinguishes brand engagement from other similar and close concepts. Although brand engagement is a very similar concept to brand involvement, it has some differences. The topic of customer engagement has been growing in relevance and complexity in the last decade [97]. Within the marketing literature, the terms "consumer engagement," "customer engagement," and "brand engagement" emerged mainly after 2005 [98].

Brand involvement has garnered enormous attention over recent decades, from both practitioners and academics, partly because of its potential influence on customer engagement [9–11]. Broadly, involvement can be described as the customer's relevance and interest IN a focal object. In this sense, customers with high levels of involvement are more likely to exhibit engagement [12] regarding thoughts, feelings, and behaviour toward a particular object [13]. Research on consumer involvement goes back to Sherif and Cantril (1947) [14]. However, although viable theories abound, there is no consensus about a definition for the term [15]. Involvement, in theory, is an individual variable, a causal and motivating variable with several consequences on the consumer's purchase and communication behavior [16].

Meanwhile, brand experience is defined as the "subjective internal consumer responses (sensations, feelings, and cognitions) and behavioural responses evoked by brand-related stimuli that are part of a brand's design, and identity, packaging, communications, and environments" [18, p. 53]. Consumer satisfaction is treated as "a global evaluative judgment about product usage/consumption" [19, p. 260].

Customer engagement in brand relationships enables greater satisfaction due to their investment in the brand [20]. Satisfaction has been criticised for failing to measure the depth of customers' responses to consumption situations and as an unreliable predictor of attitudinal loyalty. To overcome the limitations of satisfaction, the term "engagement" has emerged in academic marketing and service literature in recent years [21].

It should be emphasized that if customer engagement is an emergent construct in marketing, it has been studied in other disciplines [22]. Therefore, engagement has been previously examined across various academic disciplines, including sociology, psychology, political science, and organisational behaviour [23]. Engagement from a marketing perspective aims to know how consumers engage with a product or service [25, 98]. However, it should be noted that customer engagement and brand engagement have garnered much attention in recent research because of the broader development of the concept of engagement in marketing research [26, 27]. The research on consumer

brand engagement has grown significantly over recent years, illustrating its theoretical and practical implications [28, 29].

The remainder of the current article is divided into the following sections: Introduction, Theoretical Framework and Research Hypotheses, Research Methodology, Analysis and Results, and Conclusions.

2 Theoretical Framework and Research Hypotheses

2.1 The Effect of Brand Involvement on Customer Brand Engagement

First conceptualized by Kahn (1990, p. 694), engagement was defined as "behaviors by which people bring in or leave out their personal selves during work role performances." [30]. Since then, the term began to emerge as a psychological state (e.g., involvement, commitment, attachment, mood), performance construct (effort or observable behavior), disposition or some combination of the above, and a large amount of consensus on its definition emerged in the literature [31]. In one of the first definitions presented, Bowden (2009, p. 65) describes engagement as a "psychological process that models the underlying mechanisms by which customer loyalty forms for new customers of a service brand as well as the mechanisms by which loyalty may be maintained for repeat purchase customers of a service brand." [8]. Later, other authors focused on the behavioral dimension of engagement. For instance, van Doorn et al. (2010, p. 254) [25] define customer engagement behaviors as the "customer's behavioral manifestations that have a brand or company focus, beyond purchase, resulting from motivational drivers," while Pham and Avnet (2009, p. 2) [32] defined engagement as a "motivational state related to involvement and absorption of attention (…) to be inferred from a pattern of action or withdrawal concerning the target object".

The Marketing Science Institute (2016) considers customer engagement a key area of research that will help improve understanding of consumer behavior in complex, interactive or co-creative environments [33]. Therefore, consumer brand engagement is one of the key topics in research on marketing and consumer behaviors [20]. Customer engagement, which has its origins in the social sciences, is a new concept in marketing that attempts to bring together the numerous forms of customer non-transactional behavior [34, 35]. Adopting a broad psychological-behavioural perspective, customer brand engagement is conceptualised as referring to the strength of consumers' engagement in their relationship with a brand [36, 98].

As stated, customer engagement has attained rapidly growing attention in the last decade [7, 37, 98]. Within this emerging relational research stream [39], customer engagement's conceptualization and dimensionality are key debate topics. Reflecting some discord, differing customer engagement conceptualizations and dimensionalities have been proposed.

For example, Van Doorn et al. (2010) describe customer engagement as unidimensional and conceptualize it as "the customer's behavioural manifestation toward a brand or firm, beyond purchase, resulting from motivational drivers." [32, p. 254]. Similarly, Jaakkola and Alexander (2014, p. 248) consider customer engagement as a unidimensional construct and define it as "behaviors through which customers make voluntary resource contributions that have a brand or firm focus but go beyond what is fundamental

to transactions, occur in interactions between the focal object and/or other actors, and result from motivational drivers." [34]. Likewise, Sprott et al. (2009, p. 92) defend the one-dimensional affective approach, defining brand engagement as "an individual difference representing consumers' propensity to include important brands as part of how they view themselves" [40]. This approach is also supported by van Doorn et al. (2010), who connected customer engagement with self-schema theory and attachment theory [25]. According to Moliner-Tena et al. (2019), the one-dimensional affective approach is more faithful to the conception in the social sciences from which marketing imported the concept [33]. Higgins and Scholer (2009) and Verhoef et al. (2010) are other authors of marketing studies that treated customer engagement as a unidimensional construct [37, 41].

By contrast, most existing research has conceptualized customer engagement as a multi-dimensional construct, encompassing cognitive, affective, and behavioural dimensions [7–9, 24, 42–44, 53, 98]. For instance, Hollebeek et al. (2019: p. 167) define customer engagement as a consumer's "investment of cognitive, emotional, behavioural, and social operant, and operand resources in their brand interactions" [36], thereby exhibiting alignment with other authors [9, 23]. Other studies defined customer engagement based on five other dimensions [5, 45, 46].

The lack of consensus on the conceptualization and operationalization of customer engagement does not necessarily pose as a problem. Instead, the varied manifestations of customer engagement can imply that customer engagement is a concept that can accommodate and be approached from diverse perspectives as long as the perspective captures and explains the "nature of interaction" (e.g., type, characteristic) that customers exhibit, which can then be extrapolated for scrutiny against marketing actions in the pursuit of encouraging desired (e.g. brand loyalty) or discouraging undesired (e.g., brand switching) customer behavior.

To understand the concept of customer brand engagement it is necessary to differentiate it from other similar marketing constructs, for example, consumer brand involvement, brand attachment, self-brand connection, and brand love. Consumer brand involvement is defined as a person's perceived relevance of the brand based on inherent needs, values, and interests [47]. Brand involvement includes cognitive, affective, and motivational dimensions, whereas customer brand engagement involves attitudinal and behavioural responses toward a brand [48]. Involvement occurs due to the interest level, while highly engaged consumers invest thoughts, emotions, and behaviours due to a felt connection with the brand [49]. Consumer brand involvement predicts customer brand engagement [9, 49].

The general view of involvement emphasizes the object's relevance or importance [47, 50]. For example, Zaichkowsky (1985) defines involvement as "a person's perceived relevance of the object based on inherent needs, values, and interest" [47]. The level of consumer motivation increases as a function of felt involvement [47, 50]. If the object (e.g., brand) is relevant to the consumer, he or she is likely to exert greater cognitive efforts in analysing the object-related situations and thus analyse them in greater detail [51]. Because consumer attention is focused on object-related information, the number of object-related thoughts and inferences relative to the number of overall thoughts is larger [51]. This phenomenon reflects a deeper level of object-related cognitive elaboration [9].

Involvement is distinct from customer engagement. A customer's involvement is due to the relevance or the value of a product category for the customer, whereas customer engagement is the result of the value derived after interacting with an offering. Involvement with a product category includes cognitive (risk importance and interest) and affective (pleasure and sign) dimensions [16], whereas customer engagement involves attitudinal as well as behavioral response toward a brand. In summary, involvement occurs due to a product category's interest level, relevance, and usefulness. In contrast, an engaged customer spends resources like time, money, and effort due to a felt connection with the brand [24]. Broadly, involvement can be described as the customer's personal relevance and interest in a focal object. In this sense, customers with high levels of involvement are more likely to exhibit engagement [12] regarding thoughts, feelings, and behaviour toward a particular object [13]. Therefore, various studies [9, 24, 53] argue that customer involvement is required before expressing customer brand engagement.

Several studies have identified customer brand involvement as a determinant of customer engagement [11, 55–62, 98]. Thus, the following hypothesis is posited:

H_1: Customer brand involvement has a positive effect on customer brand engagement.

2.2 The Effect of Brand Experience on Customer Brand Engagement

Similar to engagement, researchers have strongly emphasized the vital role of experiences in marketing [18, 63]. Still, the concepts of brand experience and brand engagement remain largely unconnected. In general, brand experience is defined as "sensations, feelings, cognitions, and behavioural responses evoked by brand-related stimuli that are part of a brand's design and identity, packaging, communications, and environments" [18, p. 52]. One central difference between these two concepts seems to be that experiences do not presume a motivational state [18], whereas customer brand engagement is a motivational construct [9, 23]. However, distinguishing them is difficult in practice because they have cognitive, affective, and behavioural dimensions, and the measurement items are almost identical [9, 18]. Brakus et al. (2009) [18] divided brand experience into four dimensions: intellectual, affective, behavioural, and sensory experience. This suggests that there is likely an overlap between these two constructs.

It should be noted that since its introduction by Hirschman and Holbrook (1982), customer experience has developed into a vital consumer behaviour and marketing phenomenon [64]. Stemming from interactions between customers and particular offerings or offering-related (e.g., promotional) stimuli, customer experience describes the customer's progression through their purchase journey [65, 66].

Recent studies have confirmed the impact of brand experience on customer brand engagement [22, 58, 67, 68]. However, some studies have proven the opposite effect, i.e., the impact of customer engagement on brand experience [2, 69–73]. We will test the following hypothesis:

H_2: Brand experience has a positive effect on customer brand engagement.

2.3 The Effect of Customer Brand Engagement on Brand Satisfaction

For some studies, brand satisfaction influences brand engagement [21, 33, 54, 74]. However, based on research by Brodie et al. (2013), the customer engagement process that

consists of sub-processes, reflecting the interactive experience based on online customer interaction with the brand (company), can trigger a sense of satisfaction for customers [24]. Hollebeek et al. (2014) showed that the better the relationship between customer engagement, the more satisfied consumers are [9]. According to Rahmawati and Sanaji (2015), customer engagement significantly affects customer satisfaction [52]. Then the customer can conclude that brand engagement intensely affects customer satisfaction, based on the level of interaction and emotional ties the customer perceives. Consumer involvement in the company to learn how the openness of a brand in sharing knowledge and information with customers impacts customer satisfaction. Based on the above theory, the researchers [75–81] assume:

H_3: Customer Brand Engagement has a positive effect on brand satisfaction.

2.4 The Effect of Customer Brand Engagement on Brand Loyalty

From the buying behavioural perspective, an engaged consumer is highly involved and concerned with the whole consumption experience and thus might be likely to revisit it in the near future. In addition to prior works mentioned [82, 83]. Various authors also demonstrate the importance of emotional attachment on brand loyalty [21, 22, 26, 61, 77, 84–87]. Based on the rationales of consumer psychology and the previous findings, this study hypothesizes:

H_4: Customer brand engagement has a positive effect on brand loyalty.

2.5 The Effect of Brand Satisfaction on Brand Loyalty

Satisfaction refers to the outcome of the confirmation/disconfirmation of expectations in the post-consumption stage [88]. In other words, it is defined as the customer's sense of either enjoyment or displeasure arising from comparing the product's function and the customer's expectations [89]. In its most basic sense, loyalty towards a brand is about customer retention, repurchase, and long-term commitment. It is generally acknowledged that consumer loyalty and satisfaction are linked inseparably. Several studies proved that brand satisfaction influences brand loyalty [76, 79, 80]. Consequently, we test the following hypothesis:

H_5: Brand satisfaction has a positive effect on brand loyalty.

3 Research Methodology

The conceptual model, proposed in the present study and depicted in Fig. 1, is a model of partial mediation, where customer brand engagement and brand satisfaction are mediators of the independent variables, brand experience and customer brand involvement, and the final variable, brand loyalty. It is a pioneering model in the gaming field since customer brand involvement and brand experience are necessary to foster customer brand engagement. In turn, customer brand engagement is essential for brand satisfaction and loyalty. Finally, as has long been advocated, brand satisfaction is a fundamental predictor of brand loyalty.

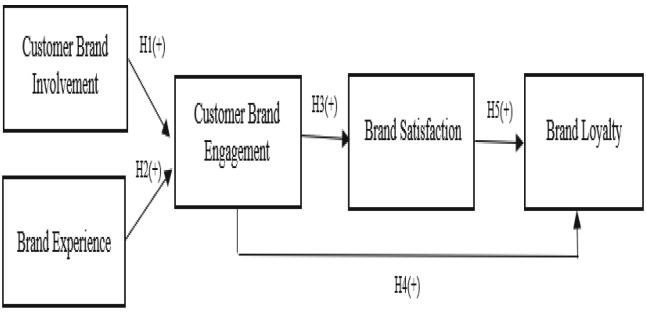


Fig. 1. Proposed Conceptual Model

3.1 Sample Selection and Data Collection

This study used a structured and self-administered questionnaire that addressed all the information needed. A sample of convenient elements was obtained by using a non-probabilistic convenience sample. Data was collected through an online survey, and 236 valid responses were received. As for the respondents' gender, we obtained responses from 41 females (17.4%) and 195 males (82.6%). Analyzing the age of the respondents, 64.4% represent ages between 18 and 30 years old. Finally, 11.8% had completed high school and 37.7% held a university degree.

3.2 Measurement Scales

The measurement scales of the constructs were based on literature and adapted to relationship marketing in the insurance context, as we can see in Table 2. All variables, presented in Table 2, were measured on a seven-point Likert scale, ranging from 1-strongly disagree to 7- strongly agree.

4 Analysis and Results

4.1 Measurement Model

An initial screening of each scale was conducted using item-total correlations and exploratory factor analysis (EFA) using SPSS 29.0. Following Anderson and Gerbing's (1988) two-step approach, a measurement model was estimated before testing the hypotheses, using a structural model [90]. The data was analyzed through confirmatory factor analysis (CFA) and structural equation modelling (SEM) using the statistical software AMOS (Analysis of Moment Structures) version 29.0. Maximum likelihood estimation procedures were used since these afford more security in samples that might not present multivariate normality.

The measurement model fits the data well ($X^2 = 267.045$, df = 94, $p < 0.001$; $X^2/df = 2.84$; IFI = 0.97; TLI = 0.96; CFI = 0.97; RMSEA = 0.089).

CFA enables the performance of tests regarding the study constructs' convergent validity, discriminant validity, and reliability. A commonly used method for estimating

convergent validity examines the factor loadings of the measured variables [90]. Factor loadings greater than 0.5 are considered very significant [91]. Also, we used the AVE to contrast convergent validity. Fornell and Larcker (1981) [92] suggested that adequately convergent valid measures should contain less than 50% error variance (AVE should be 0.5 or above). Convergent validity was achieved in this study because all the factor loadings exceeded 0.5 and all AVEs were greater than 0.5. Next, CFA was used to assess discriminant validity. If the AVE is larger than the squared correlation between any two constructs, the discriminant validity of the constructs is supported [91]. Discriminant validity is present in this study.

The composite reliability (CR) for each construct was generated from the CFA to assess reliability. The CR of each scale must exceed the 0.7 thresholds [93]. Table 1 shows that all the constructs' composite reliability coefficients are excellent, larger than 0.9. Cronbach's alpha indicator was also used to assess the initial reliability of the scales, considering a minimum value of 0.7 [94, 95]. As shown in Table 1, coefficient alpha values are all over 0.9, exhibiting high reliability. Table 1 also shows the AVE for each construct, and a correlation matrix of constructs is also shown. In Table 2, we can also see the standardized loadings and t-values of all scale items.

Table 1. Factor Correlation matrix and measurement information

Construct	CR	AVE	X_1	X_2	X_3	X_4	X_5
Brand Involvement (X_1)	.97	.91	*.97*				
Brand Experience (X_2)	.91	.93	.72	*.91*			
Brand Engagement (X_3)	.96	.90	.87	.85	*.96*		
Brand Satisfaction (X_4)	.98	.93	.73	.70	.87	*.98*	
Brand Loyalty (X_5)	.93	.81	.77	.73	.89	.90	*.93*

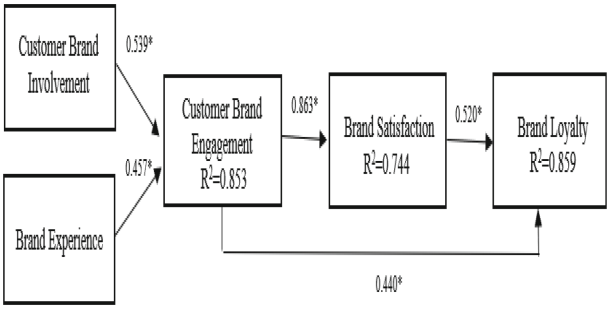
Note: In diagonal entries (italic) are Cronbach's alpha coefficients; AVE, average variance extracted; CR, composite reliability.

Table 2. Factor Correlation matrix and measurement information

Measures	Standardized Loadings	t-Value
Customer Brand Involvement Scale: Leckie et al. (2016) [54]		
Because of my personal attitudes, I feel that this brand is the brand that ought to be important to me (CBI1)	0.954	19.708
Because of my personal values, I feel that this brand is the brand that ought to be important to me (CBI2)	0.972	20.417
This brand is very important to me personally (CBI3)	0.935	19.032
Brand Experience Scale:Brakus et al. (2009) [18]		
This brand induces feelings and sentiments (BRE1)	0.864	16.442
This brand is an emotional brand (BRE2)	0.959	19.574
This brand stimulates my curiosity and problem solving (BRE3)	0.822	15.218
Customer Brand Engagement Scale:Walsh et al. (2012) [39]		
This brand is very relevant to me (CBE1)	0.948	19.515
This brand fascinates me (CBE2)	0.958	19.885
This brand is very important to me (CBE3)	0.934	18.995
Brand Satisfaction Scale:Russell-Bennett et al. (2007) [17]		
I am satisfied with my decision to purchase my preferred brand (SAT1)	0.976	20.641
My choice to purchase my preferred brand was a wise one (SAT2)	0.969	20.366
I think that I did the right thing when I decided to purchase my preferred brand (SAT3)	0.963	20.113
If I had to do it all over again, I would feel the same purchasing my preferred brand (SAT4)	0.947	19.509
Brand Loyalty Scale:Boonlertvanich (2019) [101]		
I will most likely buy this brand again (BLO1)	0.952	19.598
I will buy this brand again when I need a similar product (BLO2)	0.956	19.742
I'll 'do without' rather than buy another brand (BLO3)	0.785	14.313

4.2 Structural Model

The structural model fits the data well (X2 = 265.458 df = 98, p < 0.01 (X2/df = 2.71); NFI = 0.96, IFI = 0.97, TLI = 0.97, CFI = 0.97; RMSEA = 0.085). This model is depicted in Fig. 2. The results in Table 3 involve the analyses of the causal paths hypothesized in the structural model. The models support all the hypotheses.



Note: R^2 = Squared Multiple Correlations; *p < 0.001.

Fig. 2. Structural Model

Table 3. Estimation results of the structural model

Paths	Standardized Loadings	t-Value	Hypotheses
Brand Involvement → Brand Engagement	0.539*	11.433	H1 (+): S
Brand Experience → Brand Engagement	0.457*	9.577	H2 (+): S
Brand Engagement → Brand Satisfaction	0.863*	20.799	H3 (+): S
Brand Engagement → Brand Loyalty	0.440*	6.990	H4 (+): S
Brand Satisfaction → Brand Loyalty	0.520*	8.313	H5 (+): S

Note: * p<0.001 (one-tail tests).

However, the analysis of the total effects, direct and indirect, becomes very important since the study of the direct impact may not be revealing [96]. Thus, in Table 4, we can observe the standardized direct, indirect, and total effects. The bootstrapping technique was used with 2,000 random observations from the original sample and a 95% confidence interval.

Table 4. Standardized direct, indirect and total effects

Paths	Direct Effects	Indirect Effects	Total Effects
Brand Involvement → Brand Engagement	0.539*	-	0.539*
Brand Experience→ Brand Engagement	0.457**	-	0.457**
Brand Involvement → Brand Satisfaction	-	0.465*	0.465*
Brand Experience →Brand Satisfaction	-	0.394*	0.394*
Brand Engagement → Brand Satisfaction	0.863*	-	0.863*
Brand Satisfaction → Brand Loyalty	0.520*	-	0.520*
Brand Involvement →Brand Loyalty	-	0.479*	0.479*
Brand Experience→Brand Loyalty	-	0.406**	0.406**
Brand Engagement →Brand Loyalty	0.440*	0.449*	0.889**

Note: * $p<0.001$; ** $p<0.01$.

5 Conclusions

In gaming, customer brand involvement and brand experience are two factors that are very important to gain customer brand engagement for a game console. Putra and Murwani (2022) [61] and Rather et al. (2023) [62] demonstrated the relationship between brand involvement and customer brand engagement. In turn, Paramita et al. (2021) [68] and Huang and Chen (2022) [22] proved the effect of brand experience on customer brand engagement. It is worth highlighting the relevant role that customer brand engagement plays in achieving brand satisfaction. Shankar (2022) [81] verified this relationship. Finally, brand satisfaction is essential to foster brand loyalty. Susanti et al. (2021) [79] and Ooi et al. (2022) [80] demonstrated this effect. Customer brand engagement is also essential to get brand loyalty. Putra and Murwani (2022) [61] and Tarabieh (2022) [86] demonstrate the importance of brand engagement in fostering brand loyalty.

When we analyse the total effects (direct and indirect), we see that customer brand engagement has the most potent effect on brand satisfaction. Brand involvement is the second variable that exerts a positive indirect impact on customer brand engagement. Brand experience also plays a relevant role in developing customer brand engagement because it indirectly influences customer brand engagement. To foster brand loyalty, customer brand engagement assumes a prominent place because the total effect (direct and indirect) is powerful. Brand satisfaction is the second variable that substantially and directly impacts brand loyalty. Finally, customer brand involvement and brand experience also positively influence brand loyalty. Therefore, customer brand engagement is essential to foster brand satisfaction and brand loyalty in gaming, notably in game consoles.

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Effect of Spending on R&D and STI Activities on Firms Productivity in Ecuador

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Abstract. In a context characterized by constant technological advancement, where firms are compelled to adapt and innovate their business models to enhance productivity and efficiency, digital transformation emerges as an opportunity. To achieve this, firms typically choose to invest in research and development (R&D), or more broadly, in science, technology, and innovation (STI) activities. This research seeks to analyze the relationship between firms' R&D expenditure or spending on other science, technology, and innovation (STI) activities and business productivity, measured through firms' sales. The study employs econometric techniques based on a panel of firm-level data for the period 2012 to 2014. The results suggest that R&D expenditure and other STI activities show a positive correlation with business productivity, in line with the research hypothesis; moreover, the study identifies heterogeneous spatial effects and differences across economic sectors.

Keywords: Business Productivity · R&D Expenditure · Expenditure on Science · Technology · and Innovation (STI) Activities · Fixed Capital

1 Introduction

Digital transformation represents a necessary shift to chart a successful path toward the future, given the opportunities it offers for consolidating business productivity and generating employment within the economy [1]. In this regard, telecommunications play a key role in enabling the success of emerging business models, which are primarily characterized by disintermediation, exchange, and online collaboration [1]. In this sense, business digital transformation consists of the introduction and deepening of the use of technologies within the firm, in order to maximize its performance and efficiency—particularly in processes involving relationships with clients and suppliers, as well as in aspects related to its business model [2].

To achieve digital transformation, investment in research and development (R&D), as well as in other science, technology, and innovation (STI) activities, plays a significant role. In this regard, the Ecuadorian case is a relevant subject of study, given that in

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2023, Ecuador ranked 104th out of 132 countries in the Global Innovation Index of the World Intellectual Property Organization (WIPO), dropping six positions compared to 2022, when it ranked 98th. Among the parameters measured by this index, research and development stands out as one of the most significant components [3, 4].

Ecuador faces a number of challenges as an Andean country that relies primarily on raw materials and maintains a strong connection to the extractive sector, which accounts for approximately 20% of its GDP [2]. On the other hand, the largest share of economic activity corresponds to the services sector, which is characterized by high heterogeneity, both in terms of the intensity of knowledge utilized and the extent of activities related to innovation. From this context, a relevant research question arises: In Ecuador, what is the relationship between investment in R&D or STI activities and business productivity? Considering the availability of data for Ecuador, the objective of this article is to identify the existing association between expenditure on R&D or other science, technology, and innovation (STI) activities and business productivity, measured through firms' sales (as in [5] and [6]).

2 Related Work

Investment in science and technology plays a strategic role in business productivity, both in contexts of economic growth and competitiveness [7]. In this regard, endogenous growth theories such as that of [8] assert that increases in competitiveness and productivity are influenced by technological innovation, which generates comparative advantages and, in turn, knowledge spillovers, resulting in a higher degree of specialization. In other words, factor productivity depends on investment in research and development (R&D), which translates into a more efficient production chain [9–11].

The ultimate goal of R&D investment is the pursuit of innovation [12, 13]. [14] introduces the theory of creative destruction, a continuous innovation process in which obsolete practices are replaced by more efficient ones with higher technological components, leading to greater economic growth. In this way, firms that allocate resources to efficient research and development strategies are better positioned to introduce innovative products, services, or processes to the market [15–18]. Innovation acts as a catalyst for productivity by enabling firms to streamline operations, reduce costs, and differentiate themselves in the market [19]. For instance, investment in new technologies can automate repetitive tasks, freeing up human capital to focus on more strategic, value-added activities [20].

R&D investment enables firms to remain at the forefront in a constantly evolving market [21, 22]. By implementing a strategy of continuous improvement and adaptation, firms can respond proactively to shifts in consumer preferences, new trends, and technological advances [23–25]. This adaptive capacity contributes to enhanced competitiveness by allowing rapid responses to various market forces and by meeting consumer demands [26]. As a result, firms tend to experience increased market share and higher profitability.

The impact of investment in science and technology on productivity has been widely studied. In the work of [27], the effect of information and communication technology (ICT) spillovers on the productivity of European Union countries is examined using a

spatial Durbin model. The results indicate that variables such as the Internet usage index, connectivity index, digital skills index, e-commerce index, and e-government index have a direct and highly significant relationship with productivity. This is explained by the influence these components have on production processes and operational costs.

Continuing with the European context, [28], using a Probit model for Italian firms, determine that firm productivity increases by 0.97% following rises in technological components. Their findings also provide evidence that the impact of technology is more significant in the service sector, in larger firms, and in companies with longer market presence.

These findings remain consistent across different scenarios. The study by [29] employs autoregressive models to determine the impact of ICT on the productivity of the Russian economy. Their results align with previous findings, as they demonstrate that the digitalization of business processes and the increased proportion of organizations using Internet technologies lead to higher labor productivity. However, their model also highlights the importance of a qualified labor force.

Meanwhile, [30] analyzes the effect of robotic technology (RT) on the productivity of firms in China. Their research finds that a high RT component positively affects business productivity, provided that the firms have a high degree of task substitution. In firms with a low rate of task substitution, the effect of RT is negative. Additionally, the study suggests that the synergy between RT and productivity is influenced by factors such as technological absorption capacity, competition in the industrial market, political connections of firms, and levels of indebtedness. The empirical evidence on the direct relationship between technology and productivity in Chinese firms is consistent, as reflected in the studies of [31] and [32].

3 Data Description

In order to analyze the relationship between firms' sales levels and their investment in fixed capital, R&D expenditure, and spending on other science, technology, and innovation (STI) activities, the study considers a long panel of 6,189 firms over the period from 2012 to 2014. To the best of our knowledge, this is the most recent dataset available for a firm-level panel in Ecuador that includes identifiable information on R&D and STI expenditures. This research uses statistical data from the Science, Technology, and Innovation Activities Survey conducted by the National Institute of Statistics and Censuses (INEC) [33]. Table 1 describes each of the variables included in the analysis.

This data is presented in panel format, which facilitates the analysis of information over time and across different business entities. Moreover, the focus is on private sector firms, hence the total number of firms considered is 6,189. Table 2 presents descriptive statistics for the variables in levels.

All variables analyzed in Table 2 exhibit a marked disparity between minimum and maximum values, highlighting the diversity of conditions within each variable.

It is also notable that investment in fixed capital is significantly higher than spending on other STI activities, and compared to R&D expenditure. At the spatial (provincial) level, the data reveal high heterogeneity (descriptive statistics not reported due to space limitations), with the provinces of Pichincha and Guayas accounting for approximately

Table 1. Variable descriptions.

Variable	Type	Definition
Annual sales	Quantitative	Revenue generated by a firm in one year
Fixed capital investment	Quantitative	Expenditure on durable physical assets by a firm
R&D expenditure	Quantitative	Expenditure by a firm on research and development activities
Expenditure on other science, technology, and innovation activities	Quantitative	Expenditure on activities related to innovation, science, and technology, excluding fixed capital and R&D

Table 2. Descriptive statistics of variables.

Variable	Scope	Mean	Min	Max	Obs
Sales (thousands of USD)	Total	14290 (54967)	0.00001	1590647	N = 18567
	Between	−53092	0.00001	1533017	n = 6189
	Within	−14245	−609281	551572	T-bar = 3
Fixed capital investment (thousands of USD)	Total	598.3 (5531)	0.00001	360197	N = 18567
	Between	(4868)	0.00001	149670	n = 6189
	Within	(2627)	−119467	240730	T-bar = 3
R&D expenditure (thousands of USD)	Total	16.9 (402.1)	0.00001	30000	N = 18567
	Between	(395.9)	0.00001	30000	n = 6189
	Within	(70.1)	-3983.1	3348.6	T-bar = 3
Expenditure on other STI activities (thousands of USD)	Total	141.5 (1832)	0.00001	128431	N = 18567
	Between	(1651)	0.00001	77779.9	n = 6189
	Within	(794.2)	−54126	53584.6	T-bar = 3

Note: Standard deviation in parentheses ()

50% of all firms. This concentration is attributed to agglomeration economies present in these provinces. The data show that Pichincha records the highest levels of sales, fixed capital investment, R&D expenditure, and spending on other STI activities, followed by Guayas. For the estimations, the Galápagos (Insular province) is excluded, as business behavior there may be explained by factors different from those of mainland Ecuador. As a result, the final sample consists of 6,165 firms.

One advantage of the data provided by the Science, Technology, and Innovation Activities Survey of the National Institute of Statistics and Censuses is the ability to identify the sector in which each firm operates. Broadly speaking, and recognizing four main sectors, it is worth noting that the services sector accounts for the largest share of firms (39%), followed by the commerce sector (31%), the manufacturing industry (26%), and, finally, mining and quarrying. The next section presents the methodology and main results of the econometric estimations.

4 Methodology and Results

4.1 Methodology

To estimate the effects of R&D investment and investment in other science, technology, and innovation (STI) activities on firm productivity, this study adopts a quantitative approach based on econometric techniques applied to a panel of firms for the period 2012 to 2014. The estimation methodology using panel data allows for the presence of either random or fixed effects, as expressed in Eqs. (1) and (2):

$$Y_{it} = \alpha + \beta_1 X_{1it} + u_i + e_{it} \tag{1}$$

$$Y_{it} = v_i + \beta_1 X_{1it} + e_{it} \tag{2}$$

where Y refers to the logarithm of firm sales, used as a proxy for business productivity, and X is a vector of independent variables including the logarithm of fixed capital investment and one of the variables controlling for either R&D expenditure or, alternatively (to avoid potential multicollinearity), spending on other STI activities. The subscripts i and t refer to firms and time (t = 2012, 2013, 2014), respectively. α is a random variable representing the average constant across cross-sectional units; u is the random deviation from α; e is the stochastic disturbance term; and v is a vector of dummy variables for each country group.

The Hausman test [34] suggests the use of a fixed effects model. However, the model fails to meet the assumptions of the Gauss-Markov theorem, as it presents heteroskedasticity and autocorrelation, according to the Modified Wald test [35] and the Wooldridge test [36], respectively. At this point, the econometric literature suggests addressing these issues by estimating a Panel-Corrected Standard Errors (PCSE) model, as proposed by [37] and [38].

4.2 Results

Table 3 presents the estimations of the logarithm of firm sales—used as a proxy for productivity—as a function of fixed capital investment and one of the spending variables related to R&D or other STI activities. The table includes results from both a pooled model using Ordinary Least Squares (OLS) and a panel model with Panel-Corrected Standard Errors (PCSE). The effects of fixed capital investment are consistent across both OLS and PCSE estimates. However, the coefficients for R&D and STI investments

are reduced by approximately half in the PCSE model. This suggests substantial heterogeneity both across firms and within firms over time. The panel approach captures unobserved heterogeneity among firms, thereby improving the estimates.

The results show that fixed capital investment yields a higher return in terms of firm productivity compared to R&D or STI spending. Nevertheless, it is evident that both R&D expenditure and STI investment maintain a positive relationship with firm productivity, in line with the findings reviewed in Section II (e.g., [12, 13] for R&D investment; [28, 30] for STI spending).

The data drawn from the Science, Technology, and Innovation Activities Survey, briefly described in Section III, indicate that many firms did not invest in fixed capital and/or R&D or STI activities during one or more years of the study period (2012–2014). This could underestimate the effects of the control variables. Therefore, after the estimations reported in Table 3, the analysis was refined by excluding firms that made no investment in any of the studied categories during any year. Table 4 presents the estimations for firms that consistently invested in fixed capital and R&D or STI activities throughout the entire period.

Table 3. Estimations of business productivity.

	Pool		PCSE	
Dep. Var.: Sales (log)				
	[M1]	[M2]	[M3]	[M4]
Fixed Capital Investment (log)	0.074***	0.069***	0.071***	0.069***
	(0.003)	(0.003)	(0.004)	(0.004)
R&D Expenditure (log)	0.055***		0.027***	
	(0.005)		(0.005)	
Other STI Activities Expenditure (log)		0.032***		0.014***
		(0.004)		(0.004)
_cons	14.218***	14.091***	14.047***	13.983***
	(0.030)	(0.025)	(0.045)	(0.043)
N	18495	18495	18495	18495

Note: Robust standard errors in parentheses. Asterisks ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively

As can be seen, the effects are significantly greater than those identified in Table 3, where the return on R&D spending exceeds that of other STI activities. It is important to note that the survey used does not allow for testing the effect of agglomeration economies, as firm identification is at the provincial level. This territorial unit is not closely aligned with the concept of local labor markets, where the concentration of business, labor, social, and residential activities could be more accurately observed.

Table 4. Business productivity estimates for firms that invested throughout the entire period.

	Pool		PCSE	
Dep. Var.: Sales (log)				
	[M5]	[M6]	[M7]	[M8]
Fixed Capital Investment (log)	0.483***	0.387***	0.362***	0.309***
	(0.023)	(0.020)	(0.024)	(0.025)
R&D Expenditure (log)	0.189***		0.158***	
	(0.030)		(0.047)	
Other STI Activities Expenditure (log)		0.199***		0.122***
		(0.022)		(0.026)
_cons	8.021***	8.686***	9.827***	10.422***
	(0.321)	(0.187)	(0.415)	(0.243)
N	1005	2541	1005	2541

Note: Robust standard errors in parentheses. Asterisks ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively

4.3 Robustness Checks: Spatial and Economic Sector Heterogeneity

With respect to robustness checks, Tables 5 and 6 differentiate the effects of spending on R&D and other STI-related activities by province. However, these results should be interpreted with caution, as previously noted, provinces represent relatively large territorial units that encompass cantons with differing characteristics—particularly the denser areas such as Quito, Guayaquil, and Azuay (in that order). As shown, the effects vary across provinces, likely explained by territorial production characteristics. Nonetheless, in the remaining provinces, both R&D and other STI expenditures are associated with increases in business productivity.

Finally, Tables 7 and 8 estimate the effects by major sectors: manufacturing, services, and commerce (analyzed separately due to its relevance in the Ecuadorian economy). As evidenced, R&D expenditures show the strongest effects in manufacturing firms, while other STI-related spending is slightly more effective in the services sector. This can be explained by the nature of each sector and the relative capital- or knowledge-intensity required.

It is worth highlighting that within the services sector, there is considerable heterogeneity. This broad category includes both activities requiring highly skilled labor and others with lower skill intensity. Furthermore, as shown in Tables 7 and 8, the effects of R&D and other STI expenditures are not statistically significant in the commerce sector, which is generally characterized by lower knowledge intensity.

Table 5. Estimates of firm productivity by province, with R&D expenditure.

	Pichincha	Guayas	Azuay	Other provinces
Dep. Var.: Sales (log)				
Fixed Capital Investment (log)	0.297***	0.348***	0.558***	0.335***
	(0.038)	(0.032)	(0.107)	(0.054)
R&D Expenditure (log)	0.135	0.153***	0.044	0.329***
	(0.085)	(0.043)	(0.141)	(0.065)
_cons	10.751***	10.865***	8.495***	7.887***
	(0.700)	(0.505)	(1.588)	(0.713)
N	564	204	69	168
Firm concentration	56.1%	20.3%	6.9%	16.7%

Note: Robust standard errors in parentheses. Asterisks ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively

Table 6. Estimates of firm productivity by province, with other STI activities expenditure.

	Pichincha	Guayas	Azuay	Other provinces
Dep. Var.: Sales (log)				
Fixed Capital Investment (log)	0.271***	0.346***	0.485***	0.251***
	(0.034)	(0.035)	(0.094)	(0.057)
Other STI Activities Expenditure (log)	0.105***	0.049	0.082	0.150**
	(0.037)	(0.033)	(0.112)	(0.064)
_cons	11.272***	11.589***	8.570***	9.898***
	(0.374)	(0.396)	(0.663)	(0.548)
N	1404	363	189	585
Firm concentration	55.3%	14.3%	7.4%	23.0%

Note: Robust standard errors in parentheses. Asterisks ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively

Table 7. Estimates of firm productivity by major sectors, with R&D expenditure.

	Manufacturing	Services	Commerce
Dep. Var.: Sales (log)			
Fixed Capital Investment (log)	0.364***	0.349***	0.288***
	(0.028)	(0.036)	(0.089)
R&D Expenditure (log)	0.238***	0.173***	-0.278
	(0.036)	(0.056)	(0.286)
_cons	9.198***	9.511***	14.997***
	(0.430)	(0.602)	(2.262)
N	474	339	159

Note: Robust standard errors in parentheses. Asterisks ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively

Table 8. Estimates of firm productivity by major sectors, with other STI activities expenditure.

	Manufacturing	Services	Commerce
Var. Dep.: Ventas (log)			
Fixed Capital Investment (log)	0.307***	0.288***	0.261***
	(0.039)	(0.029)	(0.062)
Other STI Activities Expenditure (log)	0.131***	0.186***	0.121
	(0.038)	(0.033)	(0.079)
_cons	10.524***	9.592***	11.455***
	(0.320)	(0.287)	(0.966)
N	951	996	510

Note: Robust standard errors in parentheses. Asterisks ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively

5 Discussion and Conclusions

This study explores the relationship between digital transformation—approximated through spending on R&D and other STI-related (Science, Technology, and Innovation) activities—and business productivity, measured through sales. Specifically, it examines how R&D and non-R&D STI expenditures influence firm performance in Ecuador. The results indicate a positive relationship between R&D and other STI expenditures and business productivity. In other words, as spending on R&D or other STI activities increases, so does the productivity of firms. Notably, R&D spending yields slightly higher productivity returns than other STI investments.

Furthermore, the analysis reveals heterogeneous effects by province, which could be attributed to the diverse productive characteristics of different territories. Provinces represent relatively broad administrative units encompassing cantons with distinct dynamics—especially compared to denser cantons such as those found in Quito, Guayaquil, and Cuenca. In the provinces containing these cities (Pichincha, Guayas, and Azuay), significant heterogeneity exists, likely influenced not only by productive structures but also by variations in human capital, labor markets, and economic agglomeration—factors this study could not fully control for.

The study also examined the effects of R&D and other STI spending across three major economic sectors: manufacturing, services, and commerce. Results show that R&D expenditures have a greater impact in manufacturing firms, whereas other STI expenditures show slightly stronger effects in service-sector firms. This can be explained by the differing knowledge and R&D intensities required across sectors, as dictated by the nature of the activities each sector performs. In contrast, the commerce sector, which typically involves lower knowledge intensity, did not exhibit significant returns from R&D or other STI spending.

The findings align with the literature, particularly with [19], who argue that productivity is significantly influenced by innovation, which enables firms to better systematize their processes, generate added value, differentiate themselves in the market, and reduce costs. Similarly, [20] notes that R&D investment can free up human capital from automatable tasks, allowing it to be redeployed in strategic areas of the business.

In the same vein, other authors such as [15–18, 23–25], and [26] agree that R&D and STI investments enhance firms' adaptability to changes not only in technology but also in consumer preferences. These investments empower firms to introduce new processes, products, and services, thereby improving competitiveness, profitability, and productivity.

Regarding the sectoral heterogeneity observed in the effects of R&D and other STI investments, the results are consistent with [39], who find that service-sector firms are less likely to invest in R&D compared to comparable manufacturing firms, due to lower knowledge intensity in their operations. However, the services sector itself is highly heterogeneous, and within it, knowledge-intensive services (KIS) exist. Firms in this category are more likely to train employees, implement innovative organizational changes, and collaborate with external actors, resulting in higher R&D expenditure and greater sales growth compared to manufacturing firms [40]. In this regard, a positive correlation between innovation and the presence of KIS has been observed, especially in terms of R&D investment [41].

Although the impact of R&D and STI on productivity has been widely studied globally, there is limited empirical evidence for Ecuador, making this study a meaningful contribution despite certain data limitations. These findings have several policy implications for Ecuador. Given the significance of R&D and STI investment for improving business performance (with the exception of the commerce sector), the country's economic policy agenda should incorporate financial and tax incentives to foster private investment across firms of all sizes.

Ecuador's business landscape is predominantly made up of small enterprises, which face greater constraints in accessing credit and have limited capacity to adopt new technologies. Therefore, state intervention is critical—especially through the education system, which must play a key role in upgrading the national productive matrix. The goal should be to ensure that technological maturity does not rely solely on the private sector, but is also supported by a workforce with greater human capital accumulation.

Lastly, it is essential that Ecuador's statistical and census institutions (INEC) make greater efforts to collect business-level data on R&D and STI activities. This would enable deeper analyses of the country's business landscape and facilitate the development of a more responsive public policy agenda—one that is aligned with the digital transformation needs of Ecuadorian firms aiming to become more productive.

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Day Planner: An Accessible Serious Game to Support Social Communication in Children with ASD

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Abstract. This study presents the development of Day Planner, an accessible serious game designed to assist children with Autism Spectrum Disorder (ASD) in selecting appropriate clothing for different social situations and weather conditions. The goal is to support the development of social communication skills through interactive and context-based learning. The methodology comprised a literature review to identify the needs and capabilities of children with ASD, followed by the application of accessibility guidelines in the design of a game prototype. The prototype was evaluated by healthcare professionals specializing in ASD, who highlighted its potential to support children with Level 1 ASD in developing greater independence in social communication. Preliminary results indicate that the game's minimalist visual design and standardized layout, combined with realistic scenarios, contribute to its use and educational value. Professionals also recommended enhancements such as additional visual and auditory cues, clearer performance indicators, and customizable features. These findings point to future directions involving usability testing with children, aiming to refine the game's effectiveness. Day Planner represents a step forward in the development of inclusive educational tools, promoting accessibility and innovation in digital learning environments.

Keywords: Accessibility · Serious Game · Autism Spectrum Disorder (ASD)

1 Introduction

Socializing and completing various tasks can be challenging for everyone, but some people require more assistance than others. Individuals with Autism Spectrum Disorder (ASD) fall into this category. ASD is characterized by a set of features that can include difficulties in social interaction, altered or limited communication, and restricted and/or stereotyped interests and behavioral patterns [1].

In some cases, the difficulties are so severe that the individual cannot live an independent life [2]. Therefore, it is important to study and apply methods that understand the challenges faced by these individuals and that facilitate and promote their development. These methods can be applied early in life, as the diagnostic picture is often detectable in childhood.

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Children with ASD have significant difficulties communicating and socializing with their surroundings, which can lead to further challenges later in life if left untreated. As a result, educational institutions, parents, and others use specialized methods to teach and help children with ASD develop. However, because each child presents a unique set of challenges, no single method is applicable in 100% of cases, necessitating the use of different methods for different purposes. It is important to note that children with ASD may frequently be misunderstood or misinterpreted, both due to their communication difficulties and because others are unaware of these difficulties and how to interact with them. As a result, developing a game for these children can improve their communication, making it easier for them to interact with their peers and assisting in their future development. This raises the question: Is it possible to create a digital and accessible serious game that assists children with ASD in overcoming social communication challenges?

Each child with ASD has unique cognitive, motor, and behavioral challenges. As a result, the primary goal of this research is to investigate and analyze accessibility guidelines for the development of digital games aimed at children with ASD, particularly those with interaction difficulties related to social communication challenges. The specific objectives of the study were to:

- Investigate the characteristics of children with ASD who have communication and/or socialization difficulties.
- Analyze, select, and apply accessibility guidelines in the development of a serious game that is accessible to them.
- Validate the application of accessibility guidelines in the development of the game prototype.
- Assess the effectiveness of the game prototype with healthcare professionals.

To validate the selected guidelines, a prototype of a serious game Day Planner was developed to assist children with ASD in selecting clothing based on the social situation and weather conditions of the day.

The project was motivated by the desire to assist children with ASD in overcoming and addressing their social communication challenges. As a result, the idea of creating a tool to assist them was born. To achieve the research objectives, a literature review of educational and scientific materials was first conducted to gain an understanding of the users' needs, challenges, and abilities. Following that, accessibility guidelines for children with ASD were studied, analyzed, and selected. A prototype of a game was developed to validate the guidelines studied and to assist children with ASD with their social communication difficulties.

This research aims to contribute to the field of game development by providing specific accessibility guidelines for digital games aimed at children with ASD. The game prototype will benefit the community in two ways: children with ASD will be able to overcome challenges, and healthcare professionals will have a new tool to support treatment and monitoring of their patients.

This paper is divided into five sections. In addition to this introductory section, Sect. 2 presents the theoretical framework and discusses concepts related to ASD, serious games, accessibility guidelines in digital games for children with ASD, and related work. Section 3 describes the methodology, including the guidelines studied and the

development process. Section 4 presents the results and discussion following the game's development. Finally, Sect. 5 concludes the paper.

2 Theorical Background

This section presents a review of articles and scientific papers on topics relevant to the development of this project. It begins with explanations about ASD and Serious Games, followed by an explication of accessibility guidelines and related work.

2.1 Autism Spectrum Disorder (ASD)

Autism, more formally known as Autism Spectrum Disorder (ASD), is a neurodevelopmental disorder that encompasses a group of conditions that present early in a person's development, according to reference [2]. The main characteristics of ASD are persistent deficits in social communication and interaction in multiple contexts, as well as restricted and repetitive patterns of behavior, interests, or activities. It is important to consider that these symptoms are present from an early stage of development [2]. These deficits and patterns include:

- Deficits in emotional reciprocity;
- Deficits in nonverbal communicative behaviors used for social interaction;
- Deficits in developing, maintaining, and understanding relationships;
- Stereotyped or repetitive motor movements, object use, or speech;
- Insistence on sameness, inflexible adherence to routines or ritualized patterns of verbal or nonverbal behavior;
- Restricted and highly focused interests that are abnormal in intensity or focus;
- Hyper or hypo reactivity to sensory stimuli or unusual interest in sensory aspects of the environment.

According to reference [3], these characteristics can lead to difficulties for people with ASD, such as not reacting well to disruptions in routine and small changes, difficulty identifying different social contexts, disinterest in forming friendships, and difficulty establishing a normal conversation. It is important to note that not everyone with ASD will experience all these difficulties. Each individual may present a minimal number of difficulties, but to a high degree, while another may have several difficulties, but on a small scale.

Furthermore, ASD is divided into 3 levels based on the levels of support and intervention that the person with autism needs to receive. According to reference [2], the main difficulties according to the level of ASD are classified as follows:

Level 1: Requires little assistance and/or little therapeutic intervention to perform life activities, as they are mostly able to learn and/or use the resources and instructions given in most cases. Those at this level speak but have difficulty initiating and maintaining interactions and have restrictive interests and patterns that can further hinder these interactions. They also have difficulty with flexibility and change of routine.

Level 2: Requires more support and therapeutic intervention. They have greater difficulty with social interactions, even with assistance and therapeutic support. Restrictive and repetitive behaviors are more apparent. They do not like to be interrupted in their rituals and tend to become upset if this happens.
Level 3: Requires intensive support. They have a significant deficit in verbal and nonverbal communication and have very limited interaction with others. Restrictive behaviors impact all aspects of life. At this level, the symptoms are more severe, and specialized support is necessary for any progress to be made.

2.2 Serius Games

Serious games are games that are not solely designed for entertainment, but also for education and training [4]. In the oldest definition, serious games are created from the outset with the intention of educating or training, making this the biggest difference between them and entertainment-oriented games.

Serious games can be applied for training and education in various fields of study, due to their versatile nature, as they can be remodeled to meet the proposed objectives [4, 5].

2.3 Accessibility Guidelines for Children with ASD

According to reference [3], it is important to have experience with children with ASD to understand their daily needs and abilities. The ABADS institution, a school for children with developmental disabilities, uses the colors mentioned in its manual during its activities. For example, lilac, blue, and green are recommended for situations where the child is agitated. In contrast, yellow, red, and orange are recommended when the child needs to focus, concentrate, and remember, with orange being highlighted for its ability to stimulate creativity and initiative. It is important to note that these colors are intended to help children in general, including those with ASD.

Furthermore, it is important to use dynamics as a form of verbal and nonverbal communication. Some of the activities carried out at ABADS include, for example, activities for children in Level 3 of ASD, where concrete objects are used to facilitate understanding. During the activity, certain objects are offered to the children so that they can pick them up to communicate a need or intention, for example: picking up a water bottle to indicate that they are thirsty or a band-aid to show that they are hurt or in pain. In other words, using objects as an alternative way to communicate, using them symbolically. For the other levels of ASD, figures and images are used instead of concrete objects, as children in these levels have fewer difficulties. However, many children still feel the need to use concrete objects in their daily lives.

To better characterize the ABADS methodology, it is defined by dividing the children into ASD levels, that is, separating the children into groups according to the three levels [3]. By identifying key points in their main needs, specialized medical and psychological support is provided full-time to help children in their daily lives. Therapists use a variety of approaches (ABA (Applied Behavior Analysis) and Denver or TEACCH program, among others) with the ultimate goal of stimulating cognitive-behavioral development, that is, behaviors that require understanding to be executed.

WCAG Guidelines

The WCAG (Web Content Accessibility Guidelines) is a set of guidelines for accessibility in web content, so that this content can be used by everyone [6]. The WCAG is divided into four principles:

- Perceivability: the user must be able to perceive the information, i.e., alternatives to text for those who cannot read or specific colors for color blind people;
- Operability: any user should be able to operate the web page, taking into account motor difficulties, for example;
- Understandability: the content must be understandable;
- Robustness: content must be robust so that it can be interpreted by the largest number of current and future user agents, including assistive technologies.

Accessibility Guidelines for Serious Games

The study by reference [7] presents the process of designing a set of 109 guidelines, organized into 15 categories, for the development of serious games for people with ASD. It is important to note that 15 of these guidelines are specifically focused on ASD and Serious Games. These 15 guidelines are in the categories of Guidance, Explicit Control, Error Management, Compatibility, Consistency, Workload, Non-Functional Requirement, Functional Requirement, and Adaptability. These categories were defined by the authors as follows:

- Guidance: The serious game should help users with ASD in its use of messages, alarms, icons, layout, etc.;
- Explicit Control: The serious game for users with ASD should allow them to always have control, so that they can control the progress (e.g., pause, resume) of the current computer processing, etc.;
- Error Management: The serious game for users with ASD should allow them to avoid or reduce their errors;
- Compatibility: The serious game for users with ASD should take into account their characteristics (habits, skills, age, expectations, etc.) to adapt tasks to be performed, navigation, layout, etc.;
- Consistency: The serious game for users with ASD should maintain the same model of interface elements, navigation, and interaction (icon, dropdown menu, variety of options in the interface, data field, etc.);
- Workload: The serious game for users with ASD should promote their perception, concentration, attention, memory, etc.;
- Non-Functional Requirement: What the serious game for users with ASD should be or have;
- Functional Requirement: The serious game for users with ASD should have a reserved profile (access) for professionals, parents, caregivers so that they can manage access;
- Adaptability: The serious game for users with ASD should react according to the context and according to the needs and preferences of the users.

2.4 Related Work

The study by reference [8] presented Mr. Pizza, which aimed to study and analyze accessibility guidelines by creating a game and testing 16 guidelines selected by the authors.

The game itself aims to support the "development of communication, memorization, listening skills, understanding and executing a command, as well as stimulating planning and organization".

Emotiplay, developed by reference [9], is another serious game that aimed to study the effectiveness of improving emotion recognition. For this, the Emotiplay game was used, which showed simple and complex situations to teach and challenge children to understand and recognize emotions and relate them to gestures and actions. Their results showed that there was an improvement in the participants' performance in emotion recognition tasks, with some parents of participants reporting that their children's adaptive socialization also improved.

The Junior Detective Program, presented by reference [10], is an intervention program consisting of four components, including a game. The game creates a scenario in which the participant is a detective, going through a series of levels of increasing difficulty learning from recognizing how a person feels based on their speech, facial expression, and body language, to learning how to deal with more complex situations such as dealing with bullying and playing with others. The program showed, through a comparison with a waitlist control group, that participants (people with ASD) showed significant improvement in skills relevant to the program.

Based on the studies of references [8, 9] and [10] which addressed accessibility guidelines, improving emotion recognition, and intervention in the development of social skills, respectively, the research prototype for children with ASD stands out by focusing specifically on weather and social situations. The project aims to create simulations and activities that empower children to understand and deal with various weather conditions and specific social interactions.

3 Methodology

3.1 Literature Review

To initiate the project, studies were conducted on the topics of ASD, serious games, accessibility guidelines, and serious games aimed at ASD, described in more detail in the previous section. These studies were conducted through the reading of scientific papers that are important to understand the user's difficulties and, consequently, the minimum requirements of the game.

3.2 Guidelines Used in the Implementation of the Serious and Accessible Game

Considering the recommendations of the WCAG [6], the guidelines for serious games for children with autism [7] and the ABADS recommendations [3], the prototype of the game for children with ASD was developed. The game design should be minimalist, standardized in all its different screens, pay attention to how to inform possible errors, the choice of colors, the time should be more than enough to take into account the possible difficulties and that the navigation between the menus was as simple as possible, the first three guidelines being from reference [7], the following from reference [3], and the last two from reference [6].The guidelines were categorized according to the categories presented in reference [7] as shown in Table I.

Before the development phase, a visit to the ABADS organization, an educational institution focused on children with ASD and Down syndrome, was conducted, providing an enriching experience. During this visit, knowledge about the methodologies applied in working with children was acquired, and significant situations were experienced that contributed to the enhancement of the prototype (Table 1).

Table 1. Accessibility guidelines for the prototype, categorized according to reference [7]

Category	Guidelines	Source
Workload	To be minimalist	Reference [7]
Consistency	To be standardized	Reference [7]
Error Management	To inform errors cautiously	Reference [7]
Workload and Meaning of Codes (to be easily understood)	Choice of colors	Reference [3]
Explicit Control and Adaptability	Sufficient time	Reference [6]
Explicit Control	Simple navigation	Reference [6]

3.3 Abbreviations and Acronyms Tools for Prototype Construction

For the implementation of the prototype, tools such as Unity, C# Language, and Visual Studio Code were utilized. An additional resource employed during game production included AIs, including ChatGPT (personal communication, 2023), utilized as a means to identify errors in the code, and one for image generation called Gemno. Overall, these tools proved to be quite useful in expediting the development process. ChatGPT facilitated bug fixing, while Gemno enabled the generation of background images with desired palettes, rather than requiring them to be created by the authors, commissioned, or searched for (at least during an initial prototyping phase). However, it is worth noting that these technologies did not always yield satisfactory results, such as generating unrelated images or proposing code corrections that did not address the issue.

3.4 Game Proposal and Development

The game aims to assist children with ASD in everyday decision-making regarding routine changes based on weather conditions. Thus, the child is stimulated to decide what clothes to wear according to the temperature of the day, social context, and what is important to bring along. Several everyday scenarios for the child were proposed, such as going to school on a hot day. In this case, the game presents clothing options for the player to choose from, and the player must select what would be appropriate for that situation based on the location, weather, and, for instance, a suitable uniform and a blouse for hot weather.

The scenarios were divided into three contexts with different levels of difficulty. The first presents a more typical situation for the child, which is the routine of going to school on a cold day, represented as phase 1 with an easy level of difficulty. The second

addresses a more comfortable situation for the child, such as going to the park with their family on a hot day, represented as phase 2 with a medium level of difficulty. The third involves attending a friend's birthday party on a hot day, represented by phase 3 with a difficult level of difficulty. These scenarios were designed to help the child establish basic parameters for dealing with similar situations.

In addition to the scenarios, a system for choosing clothes and objects according to each context was created, aiming to provide more suitable responses to each presented situation. The child has a certain number of items that can be chosen for each specific level, in which, besides the clothes the child's character should wear, challenges are presented to bring certain objects to specific contexts. For example, at level 3, the child needs to bring items such as the gift and the party invitation to achieve the maximum score.

Based on the scenario and the situation presented, certain items were defined that, if selected by the player, would contribute to their final score, thus creating a scoring system for each phase with the aim of encouraging specific decisions and choices (positive reinforcement), rewarding the player with points at the end of the scenario.

The prototype should be responsive, usable on both mobile devices and desktops, considering the non-functional requirement that it should be presented equally to all audiences and also facilitate controls by allowing direct translation of the player's real actions in the game, instead of relying on mouse or keyboard input.

The menus and buttons were designed with a minimalist approach to make viewing, reading, and interaction clearer and more objective. The colors used were selected from palettes based on recommendations from reference [3], considering the stimuli that colors can activate. For example, colors like lilac, blue, and green are used to calm the child, while colors like yellow, red, and orange help stimulate concentration, memory, creativity, and initiative. Even the way the game communicates with the player was carefully considered, with the language used aiming to be as objective and close to the target age group (between 8 and 12 years old) as possible, using images and videos to aid in contextualization and facilitate understanding.

Regarding the game's avatar, it was intentionally left without a face. This decision stemmed from discussions regarding whether there should be different models for a female and a male character and whether the different models should have different clothes and accessories, which eventually were considered irrelevant to the original purpose of this prototype. Thus, it was agreed that the character would have no face or any gender-indicative features, allowing a broader range of users to identify with it.

Concerning the game dynamics, precautions were taken to manage errors, aiming to prevent the user from being penalized for involuntary mistakes while simultaneously avoiding demotivation in case of incorrect responses. In situations where the player makes mistakes in item selection, it is possible to adjust them before the final confirmation, as the choice only becomes definitive upon pressing the completion button, which requires player confirmation. Importantly, when displaying the final score, no indicative sound of error or punitive message is triggered, with the intention of preserving the child's emotional well-being. The decision not to use intense sounds was deliberate to avoid any negative impact.

Due to the structure employed in the prototype's development, literacy is necessary for the child to achieve optimal game functionality and independent use. However, the enhanced capabilities of the software are anticipated to be suitable for use by children with the support of therapists during treatment sessions, educators in learning environments, or family members at home, thus facilitating user development.

3.5 Game Evaluation by Healthcare Professionals

Throughout the prototype development, collaboration was sought from specialists in the Healthcare field, including professionals focused on Psychology and Speech Therapy, with experience in assisting children diagnosed with ASD. The objective was to promote constructive dialogues regarding the game concept, aiming to substantially enrich its design and contribute to the creation of a serious and accessible experience.

During the prototype evaluation stage, several meetings were held with these healthcare specialists, aiming not only to assess the game's accessibility for children with ASD but also to discuss and analyze the relevance and suitability of the proposed activities within the game.

4 Results and Discussion

The prototype was constructed based on accessibility guidelines proposed by [7], as well as [6], which include adhering to a standard layout, maintaining a minimalist visual, and avoiding the use of loud or distracting sounds. Additionally, recommendations from reference [3] regarding color usage in the game were taken into consideration, as different colors have positive impacts on various aspects.

The final version of the prototype up to the current moment has been defined with an initial menu screen with three central buttons, each serving different functionalities. The "EXIT" button functions to close the game tab, the "CREDITS" button leads to the credits screen and the "PLAY" button that directs to the game level selection screen, as depicted in Fig. 1.

The level selection screen displays the game's levels. In Level 1 (School), the child experiences a more everyday situation: going to school on a cold day. In Level 2 (Park), the child experiences a more comfortable situation: going to the park with their family on a hot day. In Level 3 (Party), the child experiences a less frequent situation: attending a friend's birthday party on a hot day. After the player selects a level, the game displays the initial screens for the context to be worked on in that level. Figure 2 shows the Initial Context Explanation Screen for Level 1.

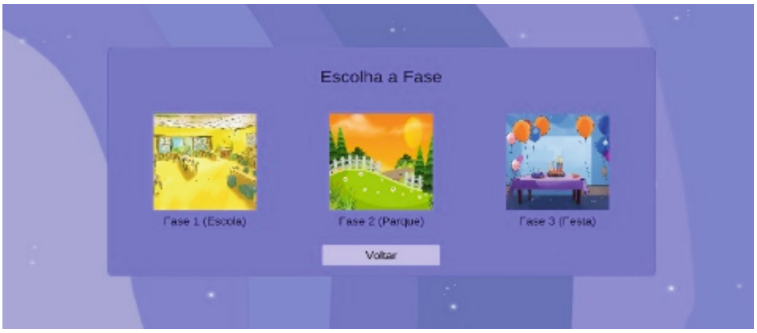

Fig. 1. Day Planner Game Level Selection Screen

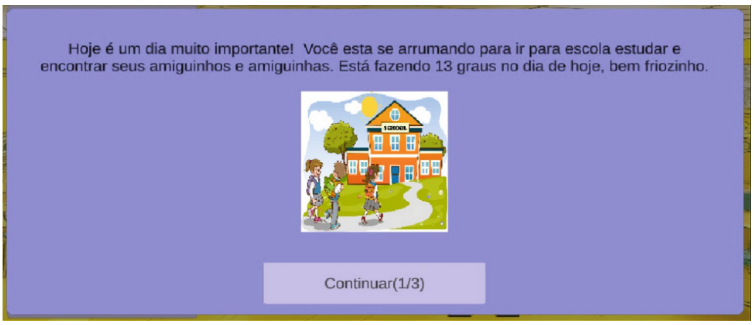

Fig. 2. Initial Context Explanation Screen for Level 1

After pressing the "Continue (1/3)" button in each level, the game proceeds to the video demonstration screen of the presented situation. The video was extracted from YouTube and has the necessary copyrights for use within the game. After pressing the "Continue (2/3)" button in each level, the game proceeds to the final scenario contextualization screen. Figure 3 shows the final scenario contextualization screen for Level 1. After pressing the "Continue (3/3)" button in each level, the game proceeds to the game screen. The player finds a clothing and object selection system where they can choose the items that best suit the scenario. The idea behind this system is to provide more appropriate responses to each situation presented.

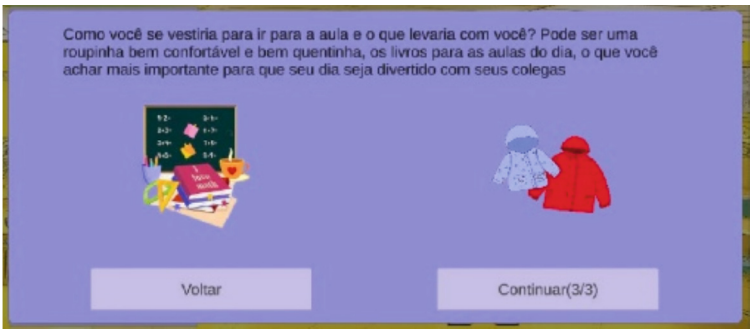

Fig. 3. Final Context Screen for Level 1

The child, assuming the role of the protagonist, has a variety of items available in each specific level. In addition to the clothes that make up their character's outfit, which is constant and unique throughout all levels, there are additional challenges that require the careful carrying of certain objects in specific contexts. For example, to achieve the maximum score in each stage of the game, it is imperative to carry the backpack and book in Level 1, the doll, robot, and ball in Level 2, and finally, the gift and party invitation in Level 3.

The choices for dressing each character in each context vary according to the temperature and location of the context. For example, in Level 1, the weather is colder and the child is going to school, so they should choose warm clothes for their character. This, together with the chosen objects, will result in the final score for the scenario as a form of positive reinforcement, stimulating the child through the point bonus system.

After the child selects the items, they must confirm their choices by submitting them and then receive their final score in each level. On the Scoring Screen in each level, the player has the option to choose three buttons: the "Level Selector" which returns to the previously mentioned level selection screen, the "Main Menu" which is the initial screen of the project, and "Exit" which closes the prototype tab.

Regarding accessibility, it is important to highlight the floating menu that is generated after pressing the "Pause" button. This menu presents four functional options for the player: the "Continue" button which closes the floating menu and continues the game session, the "Menu" button which returns to the project's initial screen, the "Explanation" button which returns to the first contextualization screen of the game and restarts the level, and the "Exit" button which closes the game.

4.1 Evaluation by Healthcare Professionals

After the game and its features were presented, the experts gave their feedback. All of them approved the game, saying that it was a good tool for children with Level 1 autism spectrum disorder (ASD), as they were able to use it alone without any external help. However, children with Level 2 or 3 ASD would need support from professionals and family members, as there are not many images or audios to guide and explain the specific objective of each level. There is only a video that provides a general context of the situation in which the level takes place.

The game was well received by psychologists, speech therapists, and professionals who work with children with ASD. All of them said that the idea of the game was interesting, in the sense that the proposed activity could be useful for developing social communication skills in children with ASD. The professionals also suggested possible improvements for the game: inclusion of more images and audios equivalent to the texts to make it more accessible to children with difficulties in interpreting text; improvement of the texts to make them more objective; inclusion of a more visual indication of performance in the level, such as using 3 stars out of 5, instead of just numerical values; addition of a video progress bar, so that the child has an idea of its duration and does not feel uncomfortable because of it; addition of the possibility to mute the video and include subtitles for it; inclusion of a congratulatory sound along with a "congratulations" text when the level is completed correctly. Ironically, the congratulatory audio issue was intentionally excluded at first, for fear that it would be distracting or disorienting.

5 Conclusions

In summary, the design and development of the game prototype presented in this project represent a significant step towards the creation of an accessible and effective tool to help children with ASD with social communication difficulties. Inspired by the guidelines proposed by the studied authors, including references [6] and [7], among others, the prototype incorporates a minimalist visual approach, avoiding distracting elements and adopting practices aligned with the specialized literature, as evidenced in the main menu screen.

The game's narrative, structured in phases that represent situations from the child's daily life, offers a unique opportunity for the development of social skills. The player's interaction, from choosing clothes to completing specific challenges, reflects the search for an educational and engaging experience. The carefully planned and contextualized phases were evaluated by healthcare professionals, whose positive feedback highlights the relevance of the game for children with Level 1 ASD.

However, the completion of this stage of the project does not represent a final point, but rather a transition point to the next phase. The suggestions of the professionals, which include improvements in accessibility, such as the addition of figures and equivalent audios, clearer visual indicators of performance and the possibility of personalizing the experience, point to a path of continuous improvement. In addition, the proposal to conduct a usability test with children with ASD demonstrates an additional commitment to the effectiveness and suitability of the game.

Thus, the completion of this stage opens doors for future iterations and improvements, aiming not only at the creation of a valuable tool, but also at its constant evolution in line with the needs and feedback of the group involved. The mission of supporting children with ASD in the development of fundamental skills gains momentum, aligned with the commitment to promote inclusion and accessibility through educational innovation.

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Education 5.0: Opportunities and Challenges from Blended Learning

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Abstract. Education 5.0 is a new paradigm in education posing many challenges and opportunities. This paper uses qualitative methods to explore students' and teachers' experiences with online learning to understand the challenges, benefits, and vision for a successful blended learning model, proposing a dynamic framework for blended learning. Results of in-depth interviews show the three main challenges of blended learning: pedagogical design, technological design, and environment/ setup design. Finally, the study discusses insights into future directions for developing Education 5.0, including the need for ongoing research, collaboration communities, curricula personalization, and innovation in the field.

Keywords: Education 5.0 · personalized learning · blended learning challenges · collaborative communities · technological/ pedagogical design

1 Introduction

The concept of Education 5.0 represents a new paradigm in the field of education, leveraging digital technologies to eliminate barriers to learning, enhance learning methods, create a learner-centric environment that leverages the latest technologies and teaching methods, and promote overall well-being [1]. We are in a post-pandemic era in which life has shifted to a digital world. This has affected many aspects of life, including education and learning, driven by the afflictions and affordances of emergency online migration [2]. This context entails several challenges in the online component of blended learning [3].

To examine these challenges and opportunities, this study used in-depth interviews to explore students' and teachers' experience with online learning to understand the challenges, benefits, and vision for a successful blended learning (BL) model. Additionally, we examine the results and considerations associated with BL. Finally, we propose insights into future directions for developing Education 5.0, including the need for ongoing research, collaboration, curricula personalization, and innovation in the field.

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2 Literature Review

2.1 Education 5.0

Education 5.0 is a novel term that aims to integrate advanced ICT technologies into the education system to enhance the learning experience and remove barriers to educating an individual [4].

The fourth industrial revolution has witnessed tremendous work towards the realization of Education 4.0 to enhance the learning experience using ICT and IoT technology [5]. On the one hand, in Education 4.0, technology plays a prominent role in the classroom, Education 5.0 upgrades Education 4.0 by exploring improvements in education systems, for instance, promoting personalized learning, collaboration, and well-being through the use of digital tools, that is, artificial intelligence (AI), virtual reality (VR), and the IoT. Additionally, Education 5.0 aims to develop 21st-century skills, such as, critical thinking, creativity, and problem-solving, rather than just memorization learning and adds immersive experience in the classrooms using ICT. The goal is to create a more efficient, effective, and equitable education system that can adapt to the changing needs of society in the fifth industrial revolution [1, 6, 7]. According to Nikum [8], Education 5.0 is more about people than technologies, focusing on creating value to identify the creative potential of human beings and enhancing education systems to address societal needs.

The concept of Education 5.0 is a relatively new field, so there is scarce academic literature specifically focused on this approach to education. However, several articles discuss related topics, namely, personalized learning, collaborative learning, communities of practice, digital technology, and AI, indicating that this field is relatively new and emerging.

Ahamad et al. [1] highlight the terms collaborative learning and personalized learning from their systematic review, which returned many articles emphasizing the need for the fundamental components in Education 5.0. Moreover, the idea of Education 5.0 centers around personalized education and collaborative learning, which has been researched for the last decade, stressing the effectiveness of online and blended learning. For instance, several researchers found that technology has the potential to support personalized learning[9], digital technology can improve access to education and support personalized learning [10], and collaborative learning can support personalized learning [11].

2.2 Blended Learning

Blended Learning (BL) is a learning model that merges diverse learning methodologies, which combines the benefits of the face-to-face (F2F) classroom learning experience with the features of an online classroom [3].

Despite the benefits BL offers higher education institutions (HEIs) in overcoming uncertainties and difficulties, it also presents some limitations and challenges to be tackled in the future. A systematic review of over 591 articles found that the main challenges and difficulties students, professors, and HEIs faced concerning blended learning experience include Self-regulation Challenges (SRC), Technological Literacy and

Competency Challenges (TLCC), Students Isolation Challenges (SIC), Technological Sufficiency Challenges (TSC) [3].

Extant research is still scarce regarding BL that challenge HEIs' policy, such as cost decision, technical support, engagement of all actors involved in BL development, and training professors and students to use this methodology [12–14]. Besides the lack of training, many teachers resist change and may not be comfortable using new technology in the classroom [15, 16]. Another BL challenge is to find the right balance between online and offline learning, as too much online learning can lead to isolation and a lack of social interaction, while too much offline learning can limit the use of technology and personalization [17].

To be substantiated with innovation, Bower et al. [18] argue that educational technology needs to intensely explore the relationships between goals, practices, cultures, learning environments, and experiences of the actors involved in its use. This stresses the role of communities of practice to tackle pedagogical challenges and foster collaboration within the service ecosystem [19].

3 Methodology

This study used in-depth interviews to explore the students' and teachers' experiences with online learning to understand the challenges, benefits, and vision for a successful blended learning model.

Data were collected online in March 2021 from students and professors with experience in online learning. The sample includes thirty interviews, 13 students, and 17 teachers from different institutions in Brazil, Portugal, France, Spain, and Germany. The sample was gender-balanced; most respondents were between 23 and 30 years old and were from different fields of knowledge. Also, diverse platforms were used for online learning, including Zoom, Google Meet, VLE, Moodle, Blackboard, E-Prof, and WhatsApp. The interview questions focus on respondents' online learning experience, namely the pandemic impact, challenges, positive and negative aspects, the support needed, and emotional state. Each interview lasted around 15–20 min.

All interviews were verbatim transcribed and analyzed using NVivo 12 software. Content analysis was used to classify and interpret patterns and categories in the data. The analysis started with an open coding process to comprehend students' and teachers' online learning experiences. Then, the codes were iteratively refined and categorized. This allowed for themes to emerge, and data explored and contrasted within and between themes, facilitating in-depth interpretation. Finally, drawing on existing literature [3, 18] the education challenges were divided into technological, pedagogical, and environmental dimensions.

4 Findings

The detailed analysis of the benefits and challenges described by teachers and students and their vision for blended learning revealed the importance of creating a supportive and collaborative experience for all. Data were organized around three major aspects: pedagogy, technology, and environment/ setup. Both educators and students consider the

design of a platform for active learning, integrating those three aspects, very important, in line with extant research [3].

4.1 Pedagogical Design

Regarding the pedagogical aspects, respondents identified several aspects that should be considered, namely (1) learning methodology adapted to BL; (2) motivation of students active participation; (3) usage of different evaluation methods (4) space for accessing information about the course methodology and contents; (5) use of gamification to promote engagement; (6) space for interactive forums to share ideas and foster collaboration; and (7) space for communities of practice. The pandemic challenged education worldwide, pushing for the acceptance and usage of online educational technologies. Professors and students are getting to know even more about educational technologies and BL methods. Thus, the need for experts in different areas of the world to share best practices has become critical, leading to the emergence of online communities of practice to share knowledge and practices. The quotes below illustrate these findings.

> "Certainly, it would be an advance if the program had proper research methods, forums organized by research themes, and integrated spaces. We would not be so dependent on the professor and would reduce the time searching for information that is scattered through YouTube, books, and other files. …. I have participated in webinars and saw people with cool ideas and research like mine, but I could not contact them to talk." [Student, 29, Germany]

> "With many professors using BL and with similar problems around the world, the international communities of practice mainly around pedagogy have significantly increased." [Professor, 44, Portugal]

4.2 Technological Design

A proper technological design is critical to support and provide a seamless BL experience. The most important aspects identified by respondents include (1) the use of artificial intelligence applied to education; (2) integrated gamification tools; (3) easy synchronization with calendar and activity planner; (4) lighter versions of the platforms to cope with slow internet; (5); possibility to upload and store audios; (6) video editing tools; (7) visualization of participants and educators in breakout rooms; (8) synchronization with different platforms and tools; and (9) direct links to data stored in drives. The quotes below show these findings.

> "I think that artificial intelligence will have a huge impact on learning tools." [Professor, 62, Portugal]

> "In online classes, I can more easily gamify my classes." [Professor, 40, Brazil]

> "Having the lessons recorded helps me when I am studying alone. I can review the content, ask questions, and have more material to study." [Student, 29, France]

Educators and students must have the necessary technological expertise to use the platforms. Educators and students identified the lack of technological competence. Furthermore, when designing learning platforms, usability, accessibility, and interoperability aspects need to be considered to facilitate, on one side, educators' teaching and, on the other side, students learning.

4.3 Environment and Setup Design

The environment and the online setup were important to facilitate blended learning. Respondents identified the following aspects: (1) space for interactions and collaboration to promote a sense of community, (2) technical and personal support, and (3) well-organized learning spaces. The sentences below illustrate these.

> "At my university during the pandemic and especially in online classes, they took great care of us, sent emails asking how we were doing, organized online activities for us to do together, and even someone came to our accommodation to support us. It was something incredible, and helped me a lot during this difficult time." [student, 28, France]

> "For sure, all these [interaction space, support from university] would help a lot during my classes, and I would be more satisfied with my learning, which would make me want to use it again and again." [Student, 29, Spain]

> "In my online class, there are people who live in the US and Europe and are also in the job market there. I have even talked to many of them about processes that I carry out in my work that are very similar to the ones they carry out in these countries. I believe it is a very good exchange of experiences." [Student, 34, Brazil]

The promotion of a space to meet other students and educators, know other students' activities, and be able to interact with people on the other side of the screen who are participating in the same learning process is very important for the success of blended learning. Also, very important is the support from the University, not only technical but, most importantly, psychological. These contribute to students' and educators' sense of community, feeling less distant, promoting mental health, and increasing satisfaction with blended learning models.

4.4 Framework for Blended Learning Environments

Figure 1 illustrates a framework showing the dynamics of blended learning. The framework shows the underlying mechanisms in a blended learning model, where different actors, i.e., students, educators, and schools, dynamically integrate different resources-pedagogical, technological, and environmental facing many challenges. Also, it identifies some factors that can facilitate BL, such as flexibility, adaptability, user-friendly design, a sense of community, and spaces for sharing knowledge and experience. This framework helps understand the BL's different aspects and challenges that can potentially enhance positive outcomes of blended learning, such as satisfaction, well-being, and learning. It is important to provide a good experience in the teaching-learning process for all actors involved. Aspects such as motivation, relationships, and mental health are

considered very important in online learning [20]. Thus, promoting engagement and a sense of community and providing support, not just technical but also emotional, are critical. Furthermore, technologies such as AI can benefit and push BL, but it is important to have a human-centered approach when designing BL platforms.

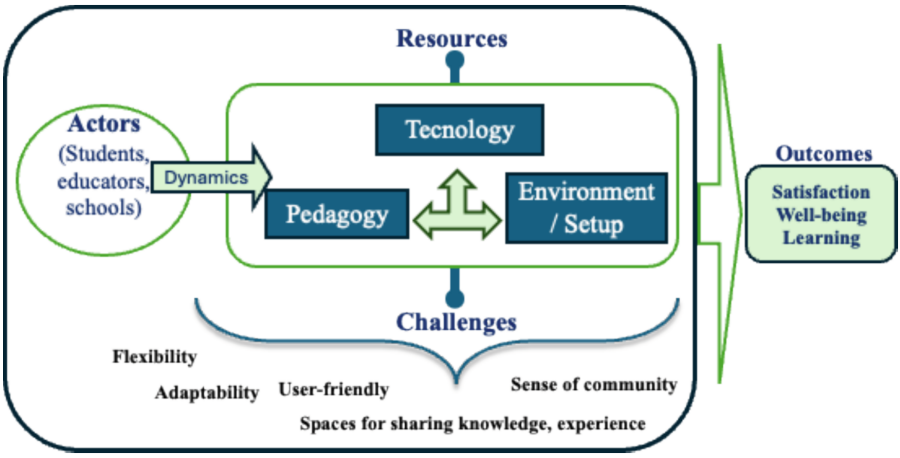

Fig. 1. A framework of the dynamics of Blended learning.

5 Discussion

This study addresses students' and teachers' experiences with online learning to understand the challenges, benefits, and vision for a successful blended learning model, using in-depth interviews to explore the themes.

The study identifies the major BL benefits and challenges that students and teachers found related to pedagogical design (e.g. gamification tools to promote engagement and space for interactivity and for communities of practice) technological design (e.g. artificial intelligence based learning tools, students and teachers' technological competencies in need) and environment and setup design (e.g. space for interactions and collaboration to promote support and sense of community).

We conclude from the proposed framework (Fig. 1) that Education 5.0 builds on BL challenges. Education 5.0 is a concept that refers to the next generation of education, which is characterized by a more personalized, learner-centric approach that utilizes technology to enhance the learning experience. It is based on the idea that education should be flexible, adaptable, and responsive to the needs of individual learners [1].

A major challenge of BL relates to the emergence of online communities of practice where people can share knowledge and support. Both educators and students consider important the design of a platform for active learning, a space for interactive forums to share ideas and best practices by experts in different areas across the world, to foster collaboration. Also, the emergence of online communities stresses the importance of creating a supportive and collaborative experience for all, which aligns with extant research [1, 3, 18].

Remarkably, communities of practice are important to tackle pedagogical challenges and foster collaboration within the service ecosystem. Communities of practice are being strengthened in many HEIs by providing expert advice from academia, which plays a crucial role in bringing together the different actors in a collaborative service ecosystem of higher-education value co-creation.

Flexibility and adaptability challenges are among the major goals of Education 5.0, which focuses on providing personalized learning experiences that adapt to the needs and abilities of individual students, providing them with well-being and satisfaction. This can be achieved using artificial intelligence and machine learning to create personalized learning curricula and adjust instruction in real time based on student needs and progress [1]. Flexibility and accessibility are two important characteristics of Education 5.0, which refers to integrating technology in education to enhance the learning experience, which aligns with previous research [4].

All these challenging components offer several contributions for HEIs reforms and policies of education innovation, requiring changes in educators' attitudes, competencies and support, textbooks, curriculum, education technologies, pedagogies, innovation, and research.

Importantly, it is essential to facilitate the development of methodological and digital competencies for all actors in BL environments. To effectively implement a personalized, technology-enabled education system, teachers and students must be trained to use new technologies that facilitate new teaching and learning methods in the Education 5.0 system.

Additionally, many teachers may resist change and feel uncomfortable using new technology in the classroom. Without proper training, a teacher may be unable to effectively use the fundamental technology and teaching methods framed on Education 5.0.

The digital divide is also a big challenge for Education 5.0 and can be a major constraint, especially in developing countries with limited resources, including Internet capacity access for supporting more advanced and high-speed technology-enabled learning tools (e.g. artificial intelligence or machine learning).

Given the noticeable role of communities of practice among learners and teachers, these collaborative communities might be crucial in designing the future university "as a service" within a holistic and customer-centered view. Communities are iterative spaces for sharing ideas and experiences, collaborating with multidisciplinary teams and actors, and have the advantage of contributing to universities achieving better results and driving customized education innovation.

Furthermore, it would benefit both universities and stakeholders (e.g. customers) to design future education services to address all societal problems with a problem-solving attitude, enhancing value co-creation. This might have a powerful contribution to transforming higher education curricula in Society 5.0

Finally, balancing online and offline learning is also challenging for Education 5.0. Especially for HEIs with BL systems. It can be difficult to certain courses to carry on online classes (e.g. laboratory practice for medical or engineering students or musical performance classes for art students) or to find the right balance between online and offline learning, as too much online learning can lead to isolation and lack of social

interaction, affecting mental health, while too much offline learning can limit the use of technology and personalization.

Overall, HEIs can overcome these challenges by creating value, identifying the creative potential of human beings to answer major societal problems through learning systems, and enhancing the education concept known as education 5.0.

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Methodology for the Development of a University Microgrid Laboratory in Virtual Reality Applied to Engineering Education

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Abstract. The COVID-19 pandemic has highlighted the need for new teaching technologies. The application of Virtual Reality (VR) in education has proven to be a great way of learning, making it more dynamic and motivating for the students. In line with the growing trend of converting real power plants into Virtual Reality (VR) simulators, this paper presents the current stage of development of a Virtual Reality Microgrid Laboratory (VRML). The physical microgrid (MG), made up of three single-phase solar photovoltaic systems of 2.6 kWp per phase, is installed in the Laboratory of Intelligent Electrical Networks (LabREI) at the Federal University of Ceará (UFC). The methodology for developing the VRML covers the following stages: collecting information of the real microgrid that is used as reference; selecting the modeling and development tools; specification of the MG objects given emphasis on technical and educational issues; modeling the MG's objects using Blender 3D software; developing the MG VR environment in the Unity 3D graphics engine; developing, testing and validating the teaching methodology; and applying the VRML as a teaching tool in the electrical engineering courses. This article presents the methodology and progress in modeling the virtual components of the MG in the Blender 3D software, as well as the initial phase of development in the Unity 3D graphics engine.

Keywords: Microgrid · Renewable Sources · Virtual Reality · Teaching · Learning

1 Introduction

Climate change and energy security are the main drivers of the energy transition, which is based on three pillars: decarbonization, decentralization and digitalization. [1]. Microgrids (MG) are a growing segment of the energy transition and represent the shift from

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centralized energy to distributed generation solutions, preferably renewable [1, 2]. However, renewable sources have an intermittent and variable nature, a challenge overcome with the use of Energy Storage Systems (ESS) with batteries [2].

MGs are small, intelligent and active electricity grids operating at low or medium voltage, made up of distributed energy resources (DERs). DERs operate as a single controllable entity to supply local loads [3] and can operate in on-grid mode, connected to the utility's electricity grid, and off-grid mode, isolated from the host grid [3].

In a digital technological environment, the structural, technological and operational transformations brought about by smart grids require educational institutions to train students with multidisciplinary knowledge and practical experience [4–6]. The development of physical laboratories has therefore become increasingly important [3, 7]. [8–10] and virtual laboratories for teaching MGs with renewable sources such as wind [11], solar [12] and ESS [13, 14].

The combination of MGs and Virtual Reality (VR) offers an innovative approach to training, allowing practice in controlled and safe environments before actual implementation. This not only enhances the practical understanding of MGs, but also optimizes the efficiency and effectiveness of training [15].

This paper presents the development of an MG Laboratory associated with Virtual Reality (VRML), developed from a physical microgrid deployed at the Laboratory of Intelligent Electrical Networks at the Federal University of Ceará (UFC).

The article is structured in six parts. Section II presents the MG of the UFC. Section III provides the methodology for developing the MG in VR, as well as the proposed teaching and assessment methodologies. The modeling of the components and the virtual environment are given in section IV and, finally, the discussions and conclusion, as well as future actions, are presented in sections V and VI, respectively.

2 Description of the University MR as the VRML Reference Mode

The MG topology of the Laboratory of Intelligent Electrical Networks (LabREI) of the Electrical Engineering Department (DEE) of the UFC. The reference model for the development of VRML is shown in the single-line diagram in Fig. 1.

LabREI's MG is connected to the university's power grid via a 35 kVA isolating transformer, whose primary winding is connected to Delta,380 V, and the secondary winding is connected to a 380 V−220 V grounded star. The primary of the isolating transformer has a general circuit breaker and a threephase power quality analyzer is connected to its secondary. The MG consists of a solar-photovoltaic (SPV) generation system made up of 30 modules with a total installed power of 7.8 kWp, which feeds two controllable load banks, one single-phase and the other three-phase. Figure 2 shows a photo of MG's PV modules, installed on the roof of the UFC's DEE.

The SFV has three single-phase subsystems (SPV-1, SPV-2 and SPV-3), made up of 10 modules each, with different operating characteristics.

SPV-1, highlighted in Fig. 1, can operate in on-grid and offgrid modes. In isolated mode, the SFV-1 subsystem operates integrated with the Energy Storage System (ESS), which feeds a group of controllable loads specified as priority loads.

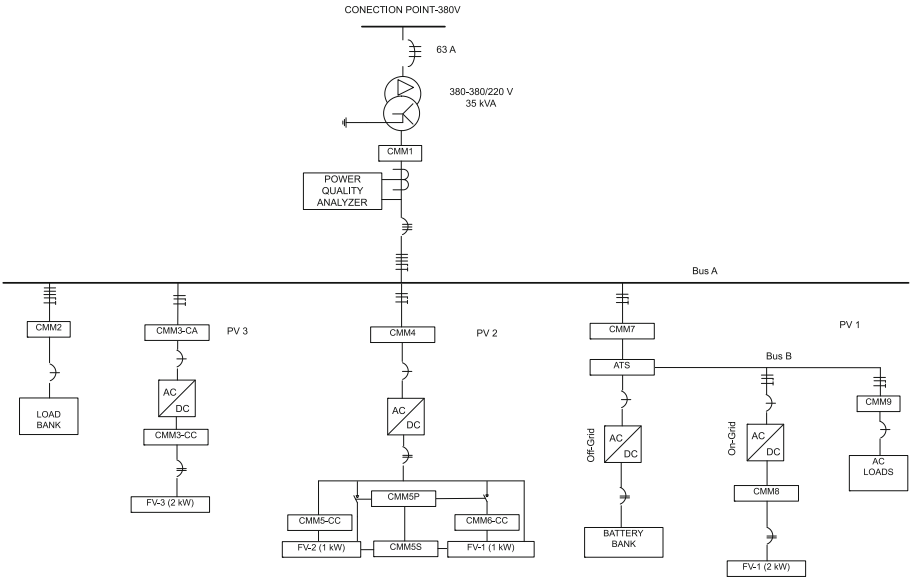

Fig. 1. Single-line diagram of the university's MG.

Fig. 2. Solar-photovoltaic modules of MG [7] and [8].

The ESS consists of four lead-acid batteries connected in series and capable of supplying a load power of 2 kW for approximately three hours.

The SPV-2, shown in Fig. 1, operates in on-grid mode, connected to the MG bus via a DC-AC inverter. This system has a control system that allows two strings of the PV plant to be connected in series or parallel, in order to provide flexibility in controlling the inverter's supply voltage level.

Finally, the SPV-3, highlighted in Fig. 1, has a control system that allows the connection to be switched in different phases of the bus. This feature allows analysis of the imbalance imposed by generation on the electricity grid.

Figure 3 shows the components of the internal environment of MG's LabREI, including the four inverters that make up the photovoltaic generation subsystem SPV-1 (Fig. 3a and b), SPV-2 (Fig. 3d) and SPV-3 (Fig. 3c), the Measurement, Protection and Control Board (Fig. 3e), the controllable loads, single-phase (Fig. 2g) and three-phase (Fig. 3f) and the Supervisory Control and Automation System (SCA) (Fig. 3h).

Fig. 3. Components of MG [7].

Further information on the design of the MG and its supervision and control system can be found in [7] and [8].

3 Methodology for the Development and Validation of the University's MG Laboratory in VR

The methodology for developing VRML includes the following steps:

1. Literature review;
2. Specification of MG's objects;
3. Modeling MG's objects;
4. Development of MG's VR environment;
5. Creation of a methodology for teaching VRML supported by VR;
6. Validation of the teaching methodology using VRML to teach REDs.

3.1 Literature Review

The need for new teaching methodologies for more effective learning in professional engineering training is in line with the high demand for multidisciplinary knowledge and personal and social skills in the training of engineering professionals. This has contributed to the use of new teaching tools, as academic institutions are increasingly being asked to develop new strategies for innovative education. In this context, VR has emerged as a very relevant solution in the academic sphere [15, 17]. There are countless benefits to virtualized simulators applied in education because, in addition to providing access to practical experiments, they provide visual learning and stimulate students' critical thinking [18].

As an example of virtualizing the learning environment, in [19] it is proposed that students develop guided activities based on a problem presented by the teachers, based on the concept of Problem Based Learning (PBL). In the proposed scenario, the students needed to develop a kitchen that was accessible to people with physical disabilities and, in order to make the prototype of this kitchen, the students used SketchUp software to carry out 3D modeling, texturing and animation. For visualization, the Cave Automatic Virtual Environment (CAVE) was chosen, which corresponds to a structure in which images of the virtual environment are projected onto walls and floors, with the aim of immersing individuals. The use of this methodology has helped to improve student performance in the course, increase their capacity for self-learning and increase their motivation.

In [20], the electronic learning (e-learning) method was used, which refers to hybrid learning, where online materials are presented in an interactive way, with resources for students to develop autonomy and improve adaptation skills. Educators, on the other hand, need to be more flexible and innovative [20]. The aim of this work is to build a virtual laboratory for learning electrical circuits. 3D Studio Max and WireFusion software were used for 3D modeling and the interactive presentation of components, respectively. Overall, this system contributes to training engineers with the skills needed for the new market context.

3.2 Specification of MG's Objects

The VRML was designed to run on a desktop connected to a multimedia projector to teach lectures. The teacher and subject monitors act as the subject monitor, interpreting teaching and learning needs, interacting with the VRML and presenting different visual and functional aspects of MG to the students. In addition, through direct communication with the students themselves, the concepts, components and subsystems of VR are explained.

The VRML requirements specification includes the hardware requirements (HR), functional requirements (FR) and non-functional requirements (NFR) and accessibility requirements (AR) listed below.

To run the software, the desktop computer must have at least the following HRs:

- HR001-RAM memory 8 Gb DDR4;
- HR002-2 GB video card;
- HR003-i5 8th Generation processor, 12 MB cache, up to 4.40 GHz;

- HR004-Use of a minimum 256 GB SSD.

It is currently planned to develop it for use with HMDs, for immersive VR and individualized use.

The following RFs were specified for VRML development:

- FR001-Access to the MG's internal environment: feature for opening the LabREI door to view the QMPC and its internal and external components, singlephase/three-phase loads, inverters and the supervision and control system.
- FR002-Drone: feature designed to access equipment and devices in more restricted spaces, such as high or remote locations, for example.
- FR003-Transformer: feature for accessing the 13,800-380/220 V isolating transformer outside the MG.
- FR004-ESS: resource for accessing the battery bank that makes up the MG's off-grid system.
- FR005-SFV modules, strings and monitoring devices: Resource for viewing SFVs (SFV-1, SFV-2 and SFV-3) and monitoring devices.
- FR006 SFV-1-Simulate SFV-1 operation in on-grid and off-grid modes.
- FR007-Simulate SFV-2 operation with strings in series or parallel.
- FR008-Simulate SFV-2 operation to generate current unbalance in the MG.
- FR009-Energy analyzer (EA) - visualize electrical quantities on the AE display to analyze the power quality of the MG.
- FR010-PLC: View events on the PLC display.
- FR011-Supervisory Control and Automation System-Resource for viewing the components of the local network and SCADA and simulated events in the MG.

VRML Non-Functional Requirements (NFR):

- NFR001-VRML availability: the VRML will be available for access in an online repository for download and local execution.
- NFR002-training time: one week of training to learn how to install and use VRML.
- NFR003-framework generation: creation of a broad model for the development of VRML, including all its computational functionalities, for the subsequent generation of similar systems in related areas, through the updating and adaptation of software components, facilitating expansions.

As far as ARs are concerned, accessibility issues have not yet been addressed during the initial development phase. However, as soon as the first validation tests with users (teachers and students-the profiles initially established for use) are carried out, the respective feedback will form the basis for new requirements that could support new functions, ranging from better visualization of elements to simplifying interactions.

3.3 Modeling Objects of the MG

To model the MG objects in VR, we looked at the main 3D modeling platforms, including Maya 3D, Blender 3D and SolidWorks. We opted to use Blender 3D due to the greater ease with which developers can use the tool [21].

3.4 Development of MG's VR Environment

We chose to use the Unity 3D platform to develop the VRML. Unity allows 3D models generated in Blender 3D to be imported and game dynamics to be implemented. When necessary, the three-dimensional meshes and textures of the modeled objects were simplified to reduce the burden of computer processing during visualization and manipulation of the VRML environment. These adjustments, however, have always taken into account maintaining the visual realism of the simulation as a whole.

At the current stage of VRML development, various behaviors have been programmed that allow objects to be moved and observed more precisely within the virtual environment, as well as physical interactions, such as opening/closing the laboratory door, switching electrical circuits on/off and using a drone to access the photovoltaic panels installed on the roof of the simulated installation.

The next steps include integrating the MG's single-line diagram into the VRML, implementing the behaviors to simulate the MG's operation in on and off-grid modes and the operation of the SPV1, SPV2 and SPV3, SCADA, loads and ESS systems.

3.5 Creation of a Methodology for Teaching VRML Supported by VR

Historically, traditional teaching methods have been used in electrical engineering courses. In [16] and [22], a traditional methodology was adopted for teaching substations in two subjects on the Electrical Engineering course at the UFC, using the VR Substation Laboratory (VRSL) applied to electrical engineering teaching.

The MG classes using VRML will be lectures held in the classroom and monitored by the teacher and the fellows working on the project. However, it will later be made available in an online repository for individual use.

Initially, the methodology employed includes a 2-h lecture on the microgrid. After the theoretical content, a specific lesson is given using VRML lasting 1 h to present the GREI virtual MG, using a multimedia projector, for classes of up to 40 students.

Face-to-face interaction between teacher and student takes place in the classroom during the use of VRML. Although it is not the current objective, it is possible that, based on the experience of using VRML, a new version will be transformed into a game environment, enabling new dynamics in individual and group teaching-learning processes.

Although development is at an early stage at the time of writing, in addition to the 3D visualization of the components, the functionalities for navigating the photovoltaic plant using drones, opening/closing doors and switching electrical circuits on/off are already available.

In subsequent phases, interaction with the other components will be implemented.

In addition to technical knowledge, classes with access to VRML can acquire new socio-emotional skills as a group, increasing participants' engagement and creativity.

As the development of the tool evolves, it is intended to adopt active methodologies in the teaching-learning process of REDs using VRML. Among the active approaches to be investigated are: project-based learning, gamification, hybrid teaching, flipped classroom and team-based learning.

3.6 Validation of the Teaching Methodology Using VRML to Teach RED

There are various evaluation methodologies applied to validating teaching using VR environments [23] and [24]. The methodologies proposed in [23] and [24] evaluate qualitative and quantitative results of the teaching-learning process using VR environments. In order to test and validate VRML applied to the teaching of REDs, the methodology proposed in [22] will be adopted, the outline of which is shown in Fig. 4.

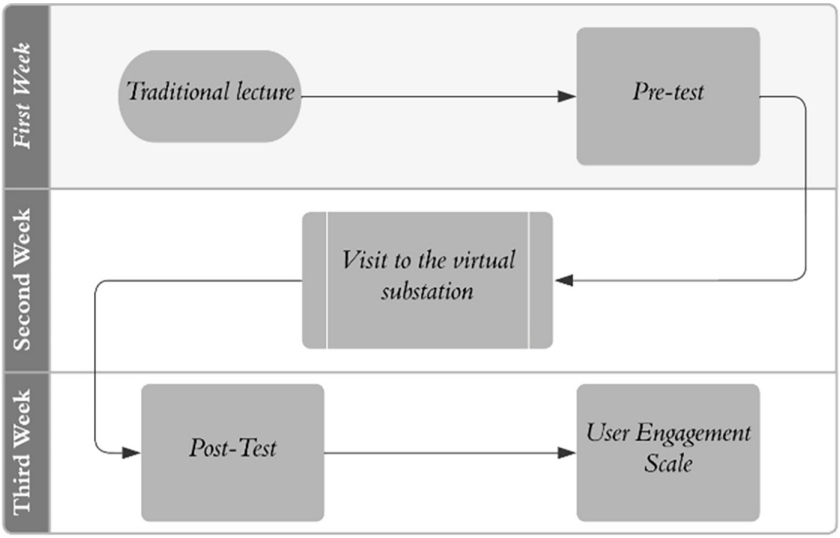

Fig. 4. Proposed teaching-learning methodology [22].

4 Modeling the MG's Components

Figure 5 shows the models of the Measurement, Protection and Control Panel (MPSC) and its components: Fig. 5(a). MPSC, Fig. 5(b). Energy analyzer, Fig. 5(c) Circuit breaker, Fig. 5(d). Contactor, Fig. 5(e). PLC, Fig. 5(f). Timer and Fig. 5(g) Disconnector switch built in Blender.

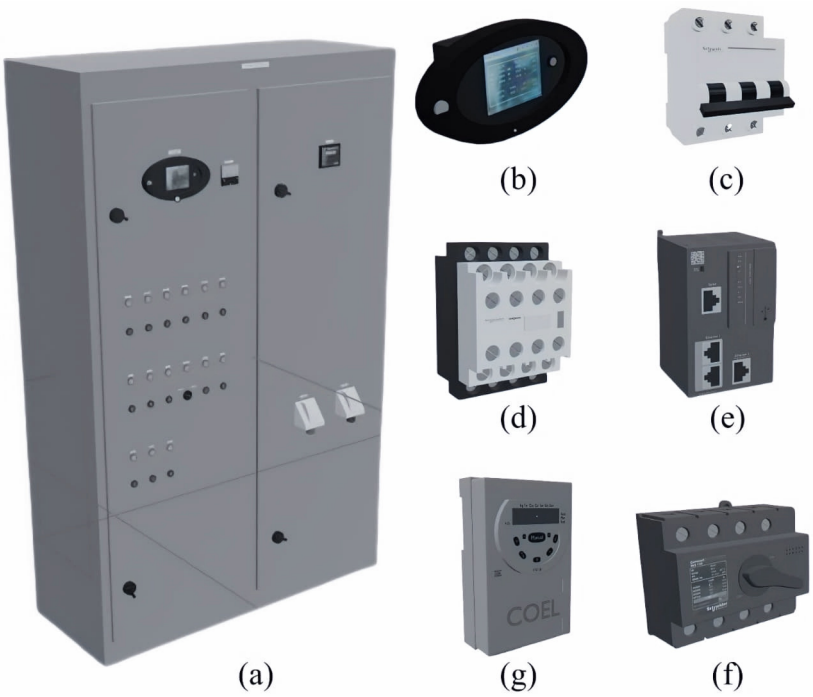

Fig. 5. Models of MPSC objects and their components.

Figure 6 shows the modeling of the single-phase (Fig. 6a) and three-phase (Fig. 6b) loads, built in Blender.

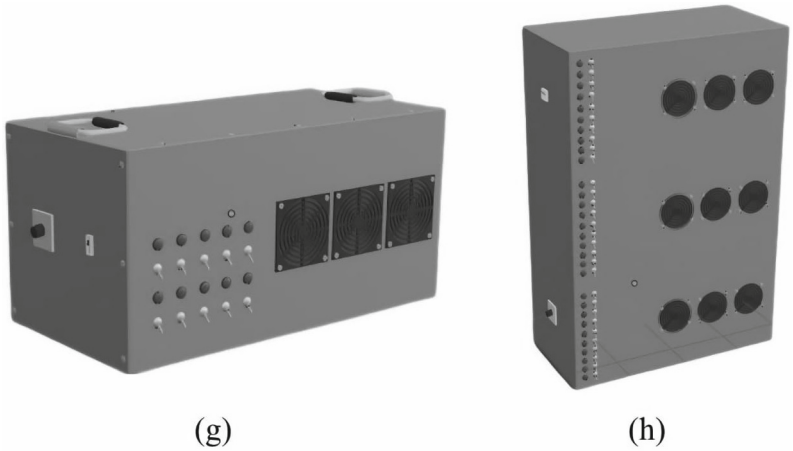

Fig. 6. Single-phase (Fig. 6a) and three-phase (Fig. 6b) load models.

Figure 7 shows the modeling of the MG inverters built in Blender: Fig. 7(a). Fronius Galvo Inverter, Fig. 7(b). Replus Inverter, Fig. 7(c). Sunny Boy Inverter, Fig. 7(d). Sunny Boy inverter.

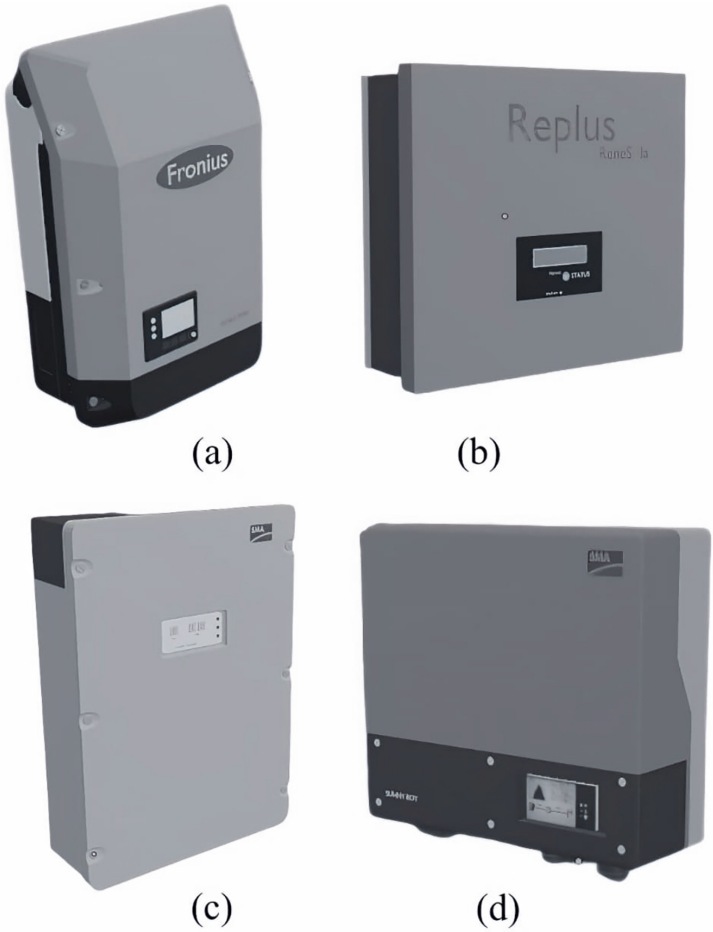

Fig. 7. MG's inverter models.

Figure 8 shows the MG photovoltaic panels on the roof built in Blender.

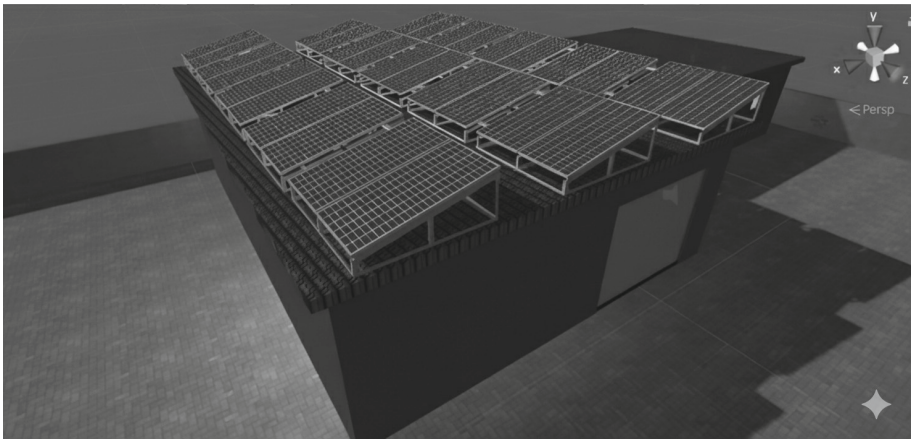

Fig. 8. Model of the MG's photovoltaic modules.

After modeling the components in Blender, the objects were imported to create the VRML environment in Unity 3D. Figure 9 shows the VRML environment developed in Unity.

Fig. 9. MG's elements in VR.

5 Discussions

In [7] and [8], the authors present the design and the supervision and control system of the real MG at LabREI, respectively. After implementing the RM and publishing their work, the authors left a great legacy for research and development. However, practical teaching in the physical VR existing at LabREI, with a detailed explanation of all its subsystems (SFV-1, SFV-2 and SFV-3), is unfeasible, given the difficult access students have to the photovoltaic plant installed on the roof of the UFC's DEE.

The VRML project's contributions include:

A modernization of teaching and learning technologies in engineering in line with modern digital media technologies.

The democratization of the teaching of renewable sources, MG and distributed energy resources, with access by teachers and students from anywhere and at any time.

Access to the complete MG environment.

A customizable laboratory that can be complemented with new REDs for teaching Green Hydrogen.

6 Conclusions

In this work, we presented the environment and tools for the development of microgrid in virtual reality. The article main purpose was to bring forth a new teaching methodology to improve technical skills knowledge through an interactive and immersive system, and provide the engineering students with technical competences as skills that enable them to better accomplish particular tasks.

The project is ever-evolving. The aim is to make the system modular so that the student can define the subsystems characteristics, and also specifying the desired components power capacity, selecting the generating source, among other technical aspects. It is also hoped to developing new REDs integrated into a green hydrogen plant for teaching in engineering courses.

In a digital era, it is perceived that modern teaching tools such as the presented Virtual Reality Microgrid Laboratory VRML can contribute to develop students competences and skills, increasing the engagement and creativity of the undergraduate individuals.

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Towards the Development of a Robust Continuous Auditing and Business Compliant System a Conceptual Proposal Using Blockchain and Machine Learning

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Abstract. Auditing can be a time-consuming task due to unintentional or deliberate errors made by the domain users. Computational methods, including machine learning and blockchain, can address these issues. Our work presents a two-step approach for a transparent automated logistics audit classification system using a combination of blockchain and machine learning. The first stage employs unsupervised learning techniques to identify distinct transaction subtypes, which are subsequently categorized manually by expert auditors. The next stage involves training a classifier, potentially using artificial neural networks, on the tagged records to enable real-time transaction classification. This enables the system to automatically detect any anomalous activity, thereby enhancing the transparency and efficiency of logistics audits, presenting a conceptual framework for a continuous and compliant audit system.

Keywords: Auditing · Anomaly detection · Intelligent systems · Blockchain · Machine learning

1 Introduction

Auditing is the process of analysis of a company's financial and accounting records to certify their accuracy. It is an arduous task due to the large number of financial transactions. These transactions may contain anomalies caused by mistakes or fraudulent practices. Audits are carried out to give confidence to potential investors or other stakeholders in the accuracy of the financial statements of the company.

Traditional auditing methods, often manual and time-consuming, struggle to keep pace with the complexity and volume of modern logistics activities. This can lead to delays, inaccuracies, and increased costs. The introduction of computational methods

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can help reduce the manual workload of auditors and improve accuracy. It can also help overcome the challenge of processing large volumes of accounting data [1].

This paper proposes a novel approach to address these challenges by leveraging the combined power of blockchain technology and machine learning (ML). We present a two-step framework for automatic logistics audit classification, aiming to create a continuous and compliant auditing system.

The integration of these technologies presents an exciting opportunity to revolutionize logistics auditing. However, it is crucial to acknowledge the evolving nature of this landscape. As new technologies are adopted, the roles and responsibilities of accountants and auditors may need to adapt to effectively operate within this changing environment. This paper delves into the potential impact on the auditing profession and explores the need for continuous learning and skill development to ensure the success of this novel approach.

2 Background

2.1 Blockchain

Blockchain is a distributed ledger technology that records transactions across multiple computers to ensure data integrity and security. In this context, using blockchain means adding trust in AI applications for auditing, by creating trust and trust networks for accounting records, with or without the involvement of trusted parties [2]. Therefore, blockchain can be viewed as an accounting technology used to transfer ownership of assets and maintain accurate financial information. Its reliability depends on trust in the system that keeps the record.

Using this distributed ledger technology for auditing offers unique capabilities for ensuring transparency, immutability, and traceability, paving the way for a more efficient and secure auditing process [3]. While still in its nascent stages, research and development efforts are exploring various methods for leveraging blockchain in the auditing domain. Here, we delve into some of the prominent methods currently being investigated.

Traditional audits typically occur periodically, leaving a gap in monitoring activities between assessments. Blockchain's continuous recording of transactions allows for real-time monitoring and verification, enabling continuous audit approaches. This continuous process can identify potential discrepancies or anomalies as they occur, leading to faster detection and mitigation of risks [4]. For example, a blockchain-based system could track inventory movements throughout the supply chain in real-time, allowing auditors to continuously monitor compliance with regulations and identify instances of potential fraud. Smart contracts, self-executing agreements stored on blockchain, can be programmed to automatically perform specific tasks based on predefined conditions. This functionality holds significant potential for automating various audit procedures. For instance, smart contracts could be designed to verify the authenticity of invoices, ensuring they haven't been tampered with and match predetermined criteria before authorizing payments. Additionally, they could automatically collect and store audit trails, streamlining data gathering and reducing manual workload for auditors.

Blockchain's inherent immutability guarantees that once data is recorded on the distributed ledger, it cannot be altered or deleted. This characteristic is crucial for ensuring the integrity and reliability of audit data. In traditional audits, concerns may arise around the potential for manipulation of data before or during the auditing process. However, blockchain technology eliminates these concerns by creating an auditable and tamper-proof record of all transactions, fostering trust and confidence during the audit process [3]. By providing a shared and immutable record of transactions accessible to all authorized participants, blockchain fosters transparency and collaboration in the auditing process. Stakeholders, including regulators, auditors, and clients, can all have access to the same data, ensuring a clear and verifiable audit trail. This transparency fosters trust among stakeholders and reduces the risk of disputes or misunderstandings [5].

While automation offers significant benefits, it is essential to acknowledge that auditors' roles will likely need to adapt as blockchain technology becomes more integrated into the auditing process [6]. The focus may shift from manual data collection and verification towards tasks like designing and deploying smart contracts, interpreting audit data generated by blockchain systems, and managing the overall security and governance of blockchain-based audit platform. This highlights the need for continuous learning and skill development for auditors to thrive in this evolving landscape.

It is important to note that the use of blockchain in auditing is still in its early stages of development, and there are several challenges that need to be addressed before widespread adoption can occur. These challenges include scalability, regulatory uncertainty, and the need for further standardization and integration with existing auditing frameworks [3]. However, the potential benefits of blockchain technology in enhancing efficiency, transparency, and trust are undeniable, making it an exciting area for continued research and development within the field of auditing.

2.2 Machine Learning

While blockchain technology is transforming the auditing landscape with its emphasis on transparency and immutability, artificial intelligence (AI), and ML in specific, are making significant strides in enhancing efficiency and accuracy within the audit process [7]. At first glance, one could assume that using smart contracts would be enough to avoid fraudulent or anomalous transactions. That is, however, not the case. Smart contracts rely on predefined rules or conditions written in code. These rules dictate what actions the contract will take when certain events occur. This can be useful to detect and avoid some types of expected "negative" transactions, but it will not prevent breaches that were not predicted by humans in the first place -- that is where ML comes into play.

Machine learning is a branch of AI that focuses on using data and algorithms to mimic the way humans learn, by building models that analyze data to make predictions, find patterns, or classify data. We discuss two types of approach: supervised and unsupervised. In supervised learning, you feed the algorithm and help it to learn, using labelled data and a set of input features. Unsupervised learning algorithms look for less obvious patterns in the data without labelled data to detect similar data clusters.

Both classes of these algorithms excel at identifying patterns and anomalies in large datasets. This capability is crucial for auditors to uncover potential red flags that might indicate fraudulent activity or even human error (i.e., data that was introduced by error).

By analyzing historical data on transactions, expenses, and other relevant parameters, ML models can learn to identify unusual patterns that deviate from expected norms. This allows auditors to prioritize areas requiring further investigation and potentially prevent fraudulent activities before they cause significant harm. Furthermore, the sheer volume of data involved in modern audits can be overwhelming for human auditors [8].

Like blockchain's potential for continuous auditing, ML models can be employed for real-time monitoring and risk assessment [9]. By continuously analyzing real-time data streams, such as financial transactions or internal control activities, these models can dynamically identify and flag potential risks as they arise. This enables proactive risk management and allows auditors to prioritize their efforts towards areas requiring immediate attention.

It is important to acknowledge that while these methods offer significant benefits, they also come with challenges. The effectiveness of ML models depends heavily on the quality of data they are trained on [10]. Despite these challenges, the integration of ML into auditing holds immense potential to improve the efficiency, accuracy, and effectiveness of the auditing process.

3 State of the Art

3.1 Machine Learning Applied to Auditing

The use of ML was carried out by different authors with the purpose of applying ML in auditing to improve accuracy and identify certain patterns in data accounting that deal to outliers. Therefore, in 2021, Wei et al. propose an unsupervised approach based on autoencoders in internal auditing. They have carried out a practical use case with an international car manufacturer and evaluated it based on two real-world production processes, and three public non-financial datasets. The results show that autoencoders can be of assistance to auditors both in the execution of the audit and in the planning of the audit [7].

In 2022, Hemati et al. proposed a continuous anomaly detection framework for regular and continuous audits, designed to learn from a stream of journal entries. An evaluation was conducted using two real-world datasets, with experimental results outlining evidence that the framework could reduce false-positive and false-negative decisions [11].

Bakumenko et al. proposed applying seven supervised ML techniques, including deep learning, and two unsupervised techniques, such as isolation forest and autoencoders. They trained and evaluated the models on a real dataset, and the results showed high potential in detecting predefined anomaly types. The supervised models achieved a recall average macro of 0.9925 using Random Forest [12].

Shinde et al. suggest two novel unsupervised model-based anomaly detection techniques based on regression and kernel density estimation. The first approach was built with regression models that identify suspicious balance sheets by giving a susceptible variable, correlated with other variables that depend and using them to build the regression model. In the second approach, followed the steps of first approach, however, use mutual information to identify variables on which the given susceptible variable has strong dependency.

Their focus is on the identification of misinformation in the financial statements by using anomaly detection techniques on a real data set of balance sheets [13].

In 2023, Kack reviews the state of the art in the detection or prediction of financial anomalies. They evaluate two anomaly detection techniques, k-NN and IF, on two sets of features: financial ratios and Beneish variables derived from the same dataset [14].

3.2 Machine Learning and Blockchain Applied to Auditing

In 2019, Shafiq presents an overview of blockchain technology and its application in the financial sector regarding anomaly detection. In this proposal, unsupervised ML techniques are used to extract transaction data from the bitcoin blockchain and analyze it for malicious transactions. Various algorithms such as Isolation Forest, Histogram-Based Outlier Detection (HBOS), Cluster-Based Local Outlier Factor (CBLOF), Principal Component Analysis (PCA), K-means, Deep Autoencoder Networks and Ensemble Method are evaluated and compared [15].

Cangemi et al. examine the issues related to auditing blockchain ledgers (BC) or distributed ledgers (DL). They list the advantages and disadvantages. They believe that audit approaches will certainly include the use of continuous controls/analytics and continuous monitoring due to the structure of these new technologies [16].

In 2020, Liu examined the operation mode of blockchain and internal auditing, analyzing application concerns and discussing the transformation of internal audit functions under this model [17].

Blockchain enables users to conduct transactions without relying on a trusted third-party intermediary. It also offers accounting benefits, such as a triple-entry accounting system that ensures immutability, real-time recording, timestamping, and encryption of all transactions. Bonynet review existing research on blockchain technology and assess its implications for the audit profession, including new risks, procedural changes, and additional opportunities [18].

4 Proposed Approach

This section outlines the technical architecture and approach for the proposed continuous auditing and business compliant system, leveraging the combined strengths of blockchain and ML techniques – both supervised and non-supervised. We do assume that the steps required to migrate the existing database to blockchain have already been taken, as the process required to perform that migration is context-dependent [19] and would be out of scope for the present manuscript. It is however important to mention that migrating the old RAW data to the blockchain presents some advantages for the system, as it does simplify future usage of the data, by having a unique source for data instead of maintaining different sources available. It also provides the benefit of added transparency and having a coherent system.

It is crucial to note that the proposed system should be designed with robust security measures in place, such as secure access controls, encryption of sensitive data on the blockchain, and regular system audits to maintain data integrity and prevent unauthorized access. By combining the transparency and immutability of blockchain with the

advanced pattern recognition capabilities of ML, this system offers a promising approach to continuous auditing and promoting business compliance in a dynamic and evolving environment.

In Fig. 1, we provide an overview of the method being proposed. It is comprised of two main phases, which we will cover in detail.

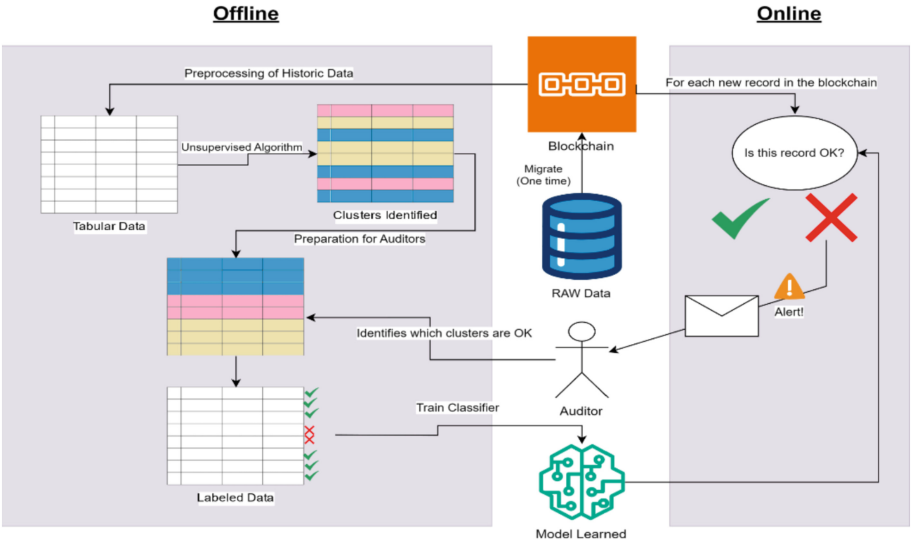

Fig. 1. A Simplified overview of the conceptual plan proposed in this document.

A-Phase 1–Dataset Preparation

In the initial phase, the system focuses on available historical audit transaction data, containing "positive" and "negative" transactions, so that it is possible to capture as much diversity as possible inside the data. This data will be uploaded onto blockchain, ensuring immutability and tamper-proof records. Domain experts then engage in the crucial task of labeling these transactions. However, given the enormous human workload required to perform this step, to expedite this process and reduce the costs, we propose the use of unsupervised ML techniques.

Unsupervised learning algorithms excel at identifying patterns and relationships within unlabeled data, such as the one presented. In this context, we can employ clustering algorithms, such as K-means or hierarchical clustering, to group similar transactions based on predefined features like transaction amount, type, recipient, timestamp, among other features that can either be already part of data (or metadata) or be artificially added to the records, by the means of feature engineering – a common practice to improve the performance of ML techniques [20].

This grouping of different records into subgroups (clusters) significantly reduces the number of individual transactions requiring manual labeling. Auditors can then efficiently assign a "positive" or "negative" class to each cluster, effectively labeling a large pool of transactions with minimal effort.

The benefits of this approach are two-fold: firstly, it alleviates the burden on auditors by reducing the volume of individual transactions requiring classification; secondly, clustering can group together transactions with similar characteristics, potentially revealing patterns indicative of fraudulent activities that might be missed when performing an isolated analysis.

It is remarkable that auditing records need to be analyzed taking their own context into account: the same record could either be "positive" or "negative", depending on its previous records (its context). For that reason, to guarantee a successful labeling of the data, we propose to do one of the following, when preparing the unsupervised task:

a) Perform feature engineering in a way that guarantees each transaction includes its contextual metadata;
b) Use unsupervised learning methods that take the context of each occurrence into account, such as using recurrent neural networks [21, 22].

Both options have their merits and disadvantages.

Option a) has the advantage that it does allow one the freedom to employ any clustering algorithm for this task. On the other hand, it requires expertise in auditing for its successful implementation – or at least should be done in collaboration with professional auditors, to understand what is the contextual information that can be important for a transaction. Questions will surely arise, such as: "How far back does the method need to look?"; "Should the previous transactions be included as part of this transaction for any case, or just when some criteria are met?"; "Do all the features included in the data provide useful information for the unsupervised task?". These kinds of questions are common when working with classical ML algorithms, that do not perform automatic feature engineering.

The biggest downside of going with option b) is the computational costs involved. Recurrent neural networks (RNNs) such as LSTMs (Long-Short Term Memory) [23] usually require specialized hardware to train, such as graphical processing units (GPUs) or, if possible, tensor processing units (TPUs), such as the ones provided by most computing cloud services nowadays. Although they have that disadvantage, they do shine with sequential data, as they were developed with that goal in mind. In the case of auditing transactions, one can just assume the time when each transaction occurred to transform the data into a sequential one, before running the unsupervised method. An aspect that is worth mentioning is that by using RNNs for unsupervised learning, one can identify not only transactions that are similar amongst them, but sequences of transactions that are similar.

The process described does provide a dataset with clusters of data. The only task left for human auditors in this phase is to manually inspect each of the clusters to understand whether they represent data of the "positive" or "negative" class and label it accordingly. It is crucial that the auditors label these clusters accurately, as these labels are going to be used for the automatic classification of transactions, as described in the following step. We do however believe that labeling by clusters instead of labeling manual transactions not only provides time advantages, but also allows the auditors to spot patterns in the data that would be ignored otherwise [24].

B-Phase 2–Supervised Learning and Continuous Monitoring
After a trustworthy labeled dataset has been built in phase one, that dataset can be used to learn a model to automatically classify new transactions, using a classification ML algorithm. Smart contracts, if used, will already filter some of the non-authorized transactions but, as mentioned before, smart contracts only filter breaches that were predicted when developing them in the first place. By adding a ML based classification detection step on top of the smart contracts, we achieve a more robust, multi-layer validation, leading to the detection of more "negative" transactions as soon as they happen.

This algorithm can either use classical algorithms such as Support Vector Machines (SVM) or Random Forests, for example, or it can be an Artificial Neural Network (ANN) with several hidden layers, usually called a Deep Neural Network (DNN) – or deep learning. Unless computational power is lacking or there is not enough data, DDNs provide better results, usually. The reason for that is that this class of algorithms not only learns how to differentiate between different classes but is also able to learn non-linear features built from the original features of the data, all in an automatic fashion. Such is done by concatenating several layers with neurons, where a non-linear function is usually applied to its outputs, in order to achieve that mathematical flexibility. Optimization techniques such as the gradient descent and its different variants such as Adam [25] are crucial for this process to work.

As with the previous step, one can also opt to use more complex and robust algorithms such as LSTMs, that capture the sequential nature of the transactions and allow the classification of sequences of transactions, similar to what previous works had done using rules on an ontology-based system [26]. The trade-offs are the same as the ones explained in the previous step – mostly related to the high computational power required for training them.

When a classification model is trained, it can be deployed and used in an online learning scenario – continuously monitoring new, unlabeled transactions on blockchain. For each new transaction (or sequence of transactions), the model predicts the probability of it being "positive" or "negative". This probability score serves as a crucial metric for flagging potentially suspicious activities. Transactions exceeding a predefined threshold score (indicating a higher likelihood of fraud) trigger alerts, prompting further investigation by responsible personnel. This continuous monitoring allows real-time detection of anomalies, potentially fraudulent activities, and user error.

One step we opted not to include into the schematic shown in Fig. 1, to keep it simple, is that the system can incorporate new data into the learning process. This allows for the system to effectively keep improving as it encounters new data, which leads to predictions that keep getting more accurate over time. Depending on the classifier chosen, this step can also be done using an online fashion (any time a new transaction is done) or using predefined triggers: either when a professional auditor detects that the system has made an error or when a certain volume of transactions has been made since the last model was trained.

5 Conclusions

This research proposed a novel approach for a continuous auditing and business compliant system that leverages the strengths of both blockchain and ML techniques. It offers significant advantages over traditional auditing methods, particularly in terms of security, efficiency, and effectiveness. One major advantage is the enhanced security provided by blockchain technology. Transactions stored on a blockchain are immutable and tamper-proof, which significantly reduces the risk of fraud or manipulation of financial records. Additionally, secure access controls and regular system audits further ensure data integrity and prevent unauthorized access. Another advantage is reducing significantly the manual workload required for traditional audits.

By employing unsupervised ML algorithms like clustering, the proposed system can automatically group similar transactions together. This drastically reduces the number of individual transactions that auditors need to manually label as "positive" or "negative," saving a considerable amount of time and resources. Furthermore, the clustering process can offer valuable insights beyond simple workload reduction. By grouping transactions with similar characteristics, the system can potentially reveal patterns indicative of fraudulent activities that might be missed by isolated analysis of individual transactions. This allows auditors to focus their attention on areas with a higher likelihood of containing suspicious activity.

The approach also addresses the challenge of incorporating context into the data labeling process. It proposes two options: feature engineering, where contextual information is explicitly included in each transaction record, or the use of recurrent neural networks (RNNs) that can inherently consider the sequential nature of the data. This ensures that the classification model considers the broader context of each transaction, leading to more accurate and reliable results. The system's continuous monitoring capabilities offer another significant advantage. By deploying a trained classification model, the system can continuously analyze new transactions occurring on the blockchain. This allows for real-time detection of anomalies and potentially fraudulent activities, as well as user errors. Transactions exceeding a predefined threshold score, indicating a higher risk of being problematic, trigger alerts for further investigation by relevant personnel. This proactive approach allows for faster identification and mitigation of potential issues. Finally, the system incorporates an adaptive learning mechanism. As new data is added to the system over time, the classification model can be continuously updated to improve its accuracy. This ensures that the system remains effective even as business practices and transaction patterns evolve.

In conclusion, the proposed conceptual plan offers a compelling solution for promoting business compliance and efficient auditing in a dynamic environment. The combined strengths of blockchain and ML provide enhanced security, reduce manual workload, improve pattern detection, and enable continuous monitoring with adaptive learning capabilities. This approach can improve the auditing landscape, leading to more secure, efficient, and effective financial oversight. It is important to highlight that this study lacks empirical evidence to support the proposed approach's effectiveness. Future work could include a pilot study or simulation results that demonstrate the system's capability in a real-world environment. Future research can also explore even more sophisticated

anomaly detection techniques and delve deeper into the integration of this system with existing auditing frameworks.

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Enhancing Urban Regeneration Through Digital Transparency and Open Government

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Abstract. This research investigates the potential of enhancing urban regeneration through the intersection of digital transparency, open government, and tax incentives in Portugal, focusing on its impact on companies from 2015 to 2022. The study employs exploratory analysis and correlation studies to understand the dynamics of a tax incentive policy for urban regeneration. The results suggest a positive correlation between the amount of tax incentives and average reconstruction activities, showing the policy's potential effectiveness in promoting urban development. However, challenges related to digital transparency, complexity, awareness, and industry alignment are identified, prompting recommendations for improvement. Recommendations for enhancing the policy's attractiveness and efficacy are discussed, emphasizing the need for improved dissemination, user-friendly platforms, and industry-tailored incentives. The research contributes valuable insights for policymakers aiming to optimize urban regeneration tax incentives and align them with sustainable development goals.

Keywords: Tax Incentives · Sustainability · Digital Transparency · Open Government · Urban Regeneration

1 Introduction

Digital transparency and open government practices have emerged as critical pillars in contemporary governance, particularly in an era marked by rapid technological advances [1]. These concepts encompass the accessibility of government data online and the integration of principles such as accountability, citizen participation, and collaboration in decision-making [2]. The literature underscores the transformative potential of digital transparency and open government in promoting democratic governance [3]. Through online platforms, governments can empower citizens by providing access to a wealth of information, ranging from budget allocations to regulatory decisions, fostering accountability and collaboration [4]. Urban regeneration, a pivotal paradigm for sustainable development within the building sector, has garnered increasing attention in contemporary discourse [5, 6]. Recognizing the substantial environmental implications associated with construction activities, there is a growing advocacy for transformative approaches that align with broader sustainability goals [7]. This recognition underscores the need

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for comprehensive strategies that address environmental concerns while fostering sustainability in the construction industry. In parallel, the demand for energy efficiency and thermal quality in buildings has become increasingly imperative, driven by factors such as population growth, rising living standards, and the urgent need to address climate change [8]. The construction sector, responsible for a significant share of carbon emissions, plays a central role in the global pursuit of sustainable urban development [9]. Sustainable practices, particularly in existing buildings, are deemed essential for achieving energy savings and addressing climate-related challenges [10]. Tax incentives, recognized as catalysts for sustainable development, have gained prominence in the discourse surrounding urban regeneration [5]. Within this context, tax incentives are crucial tools to encourage the rehabilitation of existing buildings and align with broader environmental and sustainability objectives [12]. This research aims to present the intricate dynamics of urban regeneration, specifically focusing on the Portuguese context from 2015 to 2022. Through an exploratory analysis, the authors explore the use of tax incentives for urban regeneration by companies, examining their impact on their sustainable practices. Initially, the theoretical framework is introduced. Subsequently, the attention turns to the research methodology, followed by an in-depth analysis and discussion of the results. Finally, the paper concludes with a presentation of findings and outlines potential avenues for future research. The authors believe that the findings of this research provide valuable insights to policymakers, practitioners, and researchers interested in optimizing strategies for sustainable urban development in the contemporary landscape.

2 Theoretical Background

2.1 Digital Transparency and Open Government

Digital transparency refers to the accessibility and availability of government data and information online, while open government incorporates the principles of accountability, citizen participation, and collaboration in decision-making [1]. In an era marked by rapid technological advances and the omnipresence of digital platforms, the concepts of digital transparency and open government have emerged as critical pillars of democratic governance [2]. Through online portals and platforms, governments can provide citizens with access to a wealth of data ranging from budget allocations and expenditures to performance metrics and regulatory decisions. By making this information readily available, governments empower citizens to hold them accountable for their actions and decisions [3]. Digital transparency and open government also facilitate greater collaboration between governments, civil society organizations, and other stakeholders, being essential for building trust, promoting accountability, and fostering citizen engagement in the digital age [4]. By embracing these principles, governments can harness the power of technology to create more inclusive, responsive, and effective systems of governance that serve the needs and interests of all citizens [13]. Governments around the world are recognizing the value of embracing digital transparency and open government to improve the delivery of public services, promote innovation, and strengthen democratic governance [14]. Therefore, Governments should create centralized online portals or platforms where datasets are regularly updated and organized in

a user-friendly way, making it easier for the public to find and use the information they need [15]. Governments must also invest in creating the technical infrastructure and capacity needed to support digital transparency initiatives. This includes deploying data management systems, implementing data standards and protocols, and training government officials on data literacy and open data principles [16]. Furthermore, promoting a culture of openness and collaboration within government institutions is essential to driving significant change. Governments must adopt policies and practices that prioritize transparency, accountability, and citizen involvement at all levels of decision-making. This could include creating public consultation and feedback mechanisms, introducing transparency requirements for public procurement and processes, and strengthening whistleblower protections to encourage the reporting of irregularities [17]. In short, promoting digital transparency and open government requires a multifaceted approach that includes technological innovation, institutional reform, and collaborative governance practices [18]. By adopting these strategies, governments can harness the power of technology to build more transparent, accountable, and responsive governance systems that empower citizens and promote inclusive socioeconomic development [19]. That's why the international literature shows that new technological developments enable the digitalisation of data and new information needs, placing an even greater emphasis on management systems and accounting information [20]. In the context of urban regeneration, it is crucial to disseminate tax incentives for improving the energy efficiency and thermal quality of existing buildings. This will align government public policies with the fulfilment of environmental sustainability standards.

2.2 Energy Efficiency and Thermal Quality of Buildings

The demand for energy efficiency and thermal quality of buildings is steadily increasing, driven by factors such as a growing population, higher living standards, and the impacts of climate change [8]. This has garnered attention to the critical role of building energy consumption and its associated greenhouse gas (GHG) emissions in urban sustainable development [9]. Cities play a significant role in this scenario, being responsible for 60% to 80% of global energy consumption and generating 70% of human induced GHG emissions [22]. The construction sector is a notable contributor to carbon emissions, accounting for 40% of total energy consumption and approximately 36% of global GHG emissions [9, 23]. The urgency to transform buildings into sustainable energy-efficient spaces is highlighted by the necessity to address the environmental impact of construction activities [24], driven by the current energy crisis and the European Green Deal's long-term focus on energy efficiency in buildings [25]. This has led to a deemed essential shift towards sustainability in building practices, emphasizing the critical need for proactive measures in the building sector to address climate-related challenges [10]. The introduction of the Energy Performance Certificate policy, in recent years, advocates for benchmarking the building stock to pinpoint structures requiring rehabilitation [26], being a key tool in reducing energy consumption and greenhouse gas emissions from the building sector [27]. The momentum of the green building movement is increasing worldwide, driven by the responsibility of governments and the public to control energy consumption and seek innovative and efficient alternatives for sustainable development [28]. In this context, the thermal performance assumes a crucial role in

augmenting a building's energy efficiency and mitigating greenhouse gas emissions. Recognizing thermal insulation as a key strategy, it becomes instrumental in reducing energy consumption. The integration of energy-efficient practices and the green building movement aligns seamlessly with the imperative to enhance thermal quality, thereby advancing both sustainability and environmental goals in the construction sector [29]. Achieving a low level of energy consumption is a key aspect in designing energy-efficient buildings, along with providing high standards of thermal quality. Tax incentives, which can be perceived as complex by taxpayers [35], can encourage changes in the taxpayer's behaviour and help to align objectives related to environmental sustainability with tax policies.

2.3 Tax Incentives for Urban Regeneration

The construction industry, characterized by its substantial energy consumption, has played a notable role in contributing to environmental degradation [5]. Acknowledging the inherent environmental implications associated with construction, there is a growing advocacy for urban regeneration as a pivotal paradigm for sustainable development within the building sector [6, 30]. This recognition underscores the need for a transformative approach in addressing environmental concerns and aligns with the broader goal of fostering sustainability in the construction industry [7]. Urban regeneration, operating as a "metabolic" process, involves reusing resources and rebuilding the urban environment. Beyond improving buildings' physical conditions and the urban living environment, it also contributes to enhancing a city's function and addressing urban challenges. In this context, aligning with the OECD's recommendations and aiming to foster greater innovation and the efficient use of resources, the Portuguese government took a significant step in 2015 by introducing the Green Taxation Reform through Law No. 82D/2014, effective from January 1, 2015. This reform comprises measures and proposals for tax policies strategically designed for environmental intervention across several sectors, including energy and GHG emissions [31]. Environmental taxes incentivize industries and manufacturers to prioritize eco-friendly systems and products, leading to a decline in fossil fuel usage and GHG emissions [11]. By providing financial incentives for environmentally sustainable behaviors, green taxes can help promote a greener economy and reduce the negative impact of human activities on the environment [31, 34]. When it comes to the contribution of green taxation, tax incentives are emerging as a climate policy instrument [32]. The behavior of economic agents who often adopt less desirable behavior, or unintentionally, can be influenced by tax incentives [11]. Apart from the changes introduced by the green taxation reform in Portugal, notable adjustments have been made in the context of urban regeneration. These incentives are established in the Portuguese Tax Incentives Statute in article no. 45.º - a three-year Municipal Property Tax exemption for properties over 30 years or in rehabilitation areas, extendable for five years if used for housing. Acquirers enjoy Municipal Property Transfer Tax exemption by initiating rehabilitation within three years. Additionally, conservation status assessment fees are halved for qualifying properties. These tax incentives are designed to encourage and support building rehabilitation efforts, aligning with broader environmental and sustainability goals. In theory, different property tax regimes can be used as levers to influence building development [33]. Moreover, the established property tax incentive models for

green buildings hold considerable importance, raising public awareness regarding the advantages of green buildings, and enlightening the public about the benefits associated with sustainable building practices and environmental consciousness. [36, 37]. In this sense, the synergy between government involvement, regulatory policies, and tax incentive models becomes instrumental in advancing sustainable practices within the construction industry.

3 Research Methodology

This study employs an exploratory analysis of tax incentives for urban regeneration in Portuguese companies. Using publicly available data from the Portuguese Tax Authority Portal (2015–2022) and the SABI database, a detailed database was established. The analysis includes aggregated values for Municipal Property Tax and Municipal Property Transfer Tax. Additionally, data from ODS Local, the observatory of spatial planning, and Pordata were referenced for indicators related to urban regeneration policies. SPSS software was used for descriptive analysis, and Pearson correlation was applied to explore relationships within the dataset, providing a comprehensive understanding of tax incentives and their correlation with urban regeneration indicators.

4 Results

On the results achieved, the authors verify, by analyzing Table 1, that, during the analyzed period only 330 companies took advantage of this tax incentive. Table I provides descriptive statistics related to municipalities where companies are based that have benefited from the tax incentive for urban regeneration during the period 2015–2022. The analysis involves 66 municipalities, showing a minimum of 1 and a maximum of 130 companies based on the municipality where they took advantage of the tax incentive. The mean for "Companies" is 5, indicating that each analyzed municipality has, based on average, 5 entities that accessed the tax policy under study during the period from 2015 to 2022. Similarly, the standard deviation of 17 for the number of companies implies variability in the count of entities accessing the tax policy across municipalities. The deviation from the mean of 5 indicates that some municipalities may have a higher or lower number of entities that took advantage of the tax incentive. The variable "Tax Incentives 2015–2022" reveals that the tax incentives range from a minimum of €4.82 to a maximum of €1,732,573.76 across the companies per municipality. These statistics offer a comprehensive overview of the distribution and magnitude of tax incentives in the context of urban rehabilitation across various municipalities.

Table 2 provides an overview of the tax incentives for urban regeneration that the Portuguese companies took advantage of from 2015 to 2022. Over the analyzed period, there is a consistent upward trend in the number of beneficiary companies, reaching a total of 147 in 2022. Therefore, the total amount of tax incentives granted exhibits a substantial increase, rising significantly from €78,776.33 in 2015 to €692,085.56 in 2022. Analyzing the percentage contribution to the overall total, a significant increase is evident. In 2015, the percentage was 8.18%, whereas it reached 44.55% in 2022. This suggests a substantial growth in companies engaging with the tax incentive program

Table 1. Descriptive statistics

Descriptive Statistics					
Municipality	*N*	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
Companies	66	1	130	5	17
Tax Incentives 2015–2022	66	4.82 €	1,732,573.76 €	52,891.18 €	221,964.23 €

over the years. The year 2021 stands out as a pinnacle period, both in terms of the number of beneficiary companies and the total amount granted. The percentage variation underscores a substantial year-on-year growth, indicating an increasing adoption of the tax incentive throughout the analyzed period.

Table 2. Evolution of tax incentives for urban rehabilitation that the Portuguese companies took advantage (2015–2022)

Year	N	Tax Incentives 2015–2022	% N	%Tax Incentives 2015–2022
2015	27	78,776.33 €	8.18	2.26
2016	41	120,414.29 €	12.42	3.45
2017	60	273,188.00 €	18.18	7.83
2018	80	414,405.34 €	24.24	11.87
2019	105	513,074.35 €	31.82	14.70
2020	119	651,924.37 €	36.06	18.68
2021	137	746,949.74 €	41.52	21.40
2022	147	692,085.56 €	44.55	19.83
TOTAL	330	3,490,817.98 €	100.00	100.00

Notes: Year = The year in which the tax incentive for urban rehabilitation was obtained; N = The number of companies that benefited from the tax incentive; Tax Incentives 2015–2022 = The total amount of tax incentives granted from 2015 to 2022; %N = The percentage of the number of companies that benefited from the tax incentive relative to the total; %Tax Incentives 2015–2022 = The percentage of the total amount of tax incentives granted from 2015 to 2022 relative to the total

The data from Table 3 reveals insights into the distribution of companies across several brackets of tax incentives based on mean values from 2015 to 2022. In the category of < 1000 tax incentives_mean, 11 companies were identified, dispersed across 9 municipalities. Moving to the bracket of > 1000 tax incentives_mean $< = 5000$, a larger cohort of 72 companies is spread across 30 municipalities. The next bracket, > 5000 tax incentives_mean $< = 10000$, includes 34 companies with a presence in 12 municipalities. Finally, the bracket of > 10000 tax incentives_mean encompasses 213 companies

situated in 15 municipalities. The diversity of municipalities where companies are based suggests a broad geographical distribution of tax benefits. However, concentration in some municipalities may point to specific regional development strategies. This distribution offers a nuanced understanding of the geographical and numerical distribution of companies benefiting from several levels of tax incentives.

Table 3. Brackets of tax incentives: companies and municipalities overview

Tax Incentives Mean-2015–2022	Companies	Municipalities
<1000 tax incentives_mean	11	9
>1000 tax incentives_mean < = 5000	72	30
>5000 tax incentives_mean < = 10000	34	12
>10000 tax incentives_mean	213	15
Total	330	66

Table 4 presents Pearson correlation coefficients, examining relationships between several indicators related to urban regeneration tax incentives and energy certification across different years. A noteworthy finding is a significant positive correlation (R = 66.3%) between the amount of tax incentives granted to Portuguese companies and the municipality where they are based (Tax Incentives-2015–2022) and the average reconstruction (Reconst_mean). This suggests that higher tax incentives in municipalities where beneficiary companies are based are associated with higher average reconstruction activity. Additionally, significant positive correlations are observed between consecutive years of reconstruction (Reconst_2015 to Reconst_2022), indicating a consistent trend where reconstruction activities in one year positively influence the following year. Specifically, these policies promote the regeneration of existing urban structures over new construction. This correlation between consecutive years of reconstruction suggests that the tax incentives might have contributed to a sustained trend in prioritizing urban regeneration, which is reflected positively in subsequent years. This is consistent with authors who argue for the positive impact of tax policies on improving the overall built environment and encouraging sustainable practices [31, 33, 34]. However, there are no significant correlations between different years of energy certification (Certif_2014 to Certif_2018) or the average certification (Certif_mean). This suggests that the proportions of better energy-certified buildings do not exhibit a significant consistent trend over the analyzed years. In this context, it is important to emphasize that the average certification values per municipality exhibit a narrow range from 23.5 to 59.5, with an overall mean of 45.5. This indicates a relatively consistent standard in the average energy certification values across the 66 municipalities where the beneficiary companies of the tax policy under study are headquartered, which may explain why there is no significant correlation with the total amount of tax incentives per company and municipality where companies are based. The lack of a significant correlation could be attributed to the complexity of factors influencing energy certification, extending beyond the direct impact of tax incentives [25]. Other elements, such as local regulations, community practices, and

specific building characteristics, may play a more prominent role in obtaining energy certification [27], resulting in the absence of a clear relationship with tax incentives.

Table 4. Correlation analysis of urban rehabilitation indicators

Correlations (Tax Incentives-2015–2022)		
Reconst_2015	(R)	**0.285***
	ρ	0.020
Reconst_2016	(R)	**0.663****
	ρ	0.000
Reconst_2017	(R)	**0.426****
	ρ	0.000
Reconst_2018	(R)	**0.317****
	ρ	0.010
Reconst_2019	(R)	0.130
	ρ	0.300
Reconst_2020	(R)	**0.312***
	ρ	0.011
Reconst_2021	(R)	0.059
	ρ	0.638
Reconst_2022	(R)	0.094
	ρ	0.452
Reconst_mean	(R)	**0.432****
	ρ	0.000
Certif_2014	(R)	0.181
	ρ	0.145
Certif_2015	(R)	0.156
	ρ	0.212
Certif_2016	(R)	0.061
	ρ	0.625
Certif_2017	(R)	0.126
	ρ	0.315
Certif_2018	(R)	0.141
	ρ	0.260

(*continued*)

Table 4. (*continued*)

Correlations (Tax Incentives-2015–2022)		
Certif_mean	(R)	0.137
	ρ	0.272

*Notes: Pearson Correlations (ρ) are significant at * the 0.05 level (2-tailed) and ** the 0.01 level (2-tailed); Reconst_year = Reconstructions completed per 100 new constructions completed (No.) per year; Certif_year = Proportion of buildings with energy certification rated A +, A, B, B-, and C in the municipalities of Portugal (%) per year; Reconst_mean = Average number of reconstructions completed per 100 new constructions completed in the period from 2015 to 2022; Certif_mean = Mean proportion of buildings with energy certification rated A +, A, B, B-, and C in the municipalities of Portugal in the period from 2014 to 2018 (Available data)*

The analysis underscores challenges in the effectiveness of Portugal's tax incentive policy for urban rehabilitation. Issues include insufficient dissemination through municipalities, complex regulations causing limited adherence [35], and a lack of digital transparency hindering accessibility for businesses [1, 13, 19]. Additionally, low public awareness, the absence of user-friendly online platforms, and perceived gaps in open government practices contribute to reduced engagement. The policy's failure to align with industry needs further diminishes its appeal. Addressing these concerns is crucial for enhancing the policy's efficacy and fostering increased participation and relevance to industry challenges.

5 Conclusions

There is growing support for transformative approaches to construction that are aligned with broader sustainability goals. This recognition highlights the need for comprehensive strategies that address environmental concerns while promoting sustainability in the construction industry. This study has undertaken an exploratory analysis of the tax incentive for urban regeneration in Portugal, with a particular focus on its effectiveness and impact on sustainable urban development. The methodology examined companies that took advantage of the urban regeneration tax incentive and the municipalities in which they were based between 2015 and 2022. Data was obtained from 330 beneficiary companies based in 66 municipalities. The results indicate an upward trend in the amount of tax incentives granted and the number of companies, suggesting a growing engagement with the tax incentive program. Particularly, the year 2021 stands out as a pinnacle period, demonstrating substantial year-on-year growth. This points towards an increasing adoption of the tax incentive throughout the analyzed period, indicating its relevance and impact on the construction sector. The findings also reveal a positive correlation

between the amount of tax incentives granted to Portuguese companies and the municipality where they are based, and the average reconstruction, highlighting the potential effectiveness of tax incentives in promoting urban regeneration. This aligns with the broader goals of sustainable development, recognizing the importance of transforming existing urban spaces for improved environmental outcomes [21, 33, 34]. Furthermore, there are significant positive correlations between consecutive years of reconstruction, indicating a consistent trend where reconstruction activities in one year have a positive influence on the following years. Nevertheless, there are no correlations observed among the several years of energy certification or the average certification, when compared to the amount of the tax incentives. This finding may be attributed to several factors, including local regulations, community practices, and specific building attributes, which may exert a more significant influence on the attainment of energy certification [25, 27], leading to the lack of a discernible relationship with tax incentives. This statement reinforces the importance of government involvement in promoting the dissemination of public policies that recognize the environmental implications associated with the construction sector. In this regard, digital transparency and open government practices are emerging as essential pillars for the sustainable development of cities. However, challenges remain in effectively implementing the tax incentive policy. Critical factors that may impede the optimal engagement of local businesses include issues related to digital transparency, tax complexity, and public awareness. Policymakers need to reassess and enhance the existing policy framework to address these challenges. Improving digital transparency through user-friendly online platforms and clear communication channels can facilitate better dissemination of information, making it more accessible to businesses [15]. Additionally, simplifying tax regulations and providing comprehensive guidelines can reduce hesitancy and confusion among potential beneficiaries, fostering increased participation [35]. The link between tax policies and open government practices is crucial for creating a governance system that is not only transparent but also responsive to the needs of stakeholders [13]. Future research could explore several key areas. Firstly, an exploration of the legislative evolution surrounding tax policies for urban regeneration in Portugal is warranted. Examining how tax regulations have transformed over time would involve identifying substantial changes and adaptations within the legal framework. Understanding how these changes influenced the engagement of businesses in tax incentive programs and whether they effectively promoted urban regeneration is essential. Another avenue for exploration lies in understanding the barriers faced by businesses in effectively implementing tax incentives. Potential solutions to address issues such as digital transparency, tax complexity, and public awareness should be proposed to overcome these obstacles. The research contributes valuable insights for policymakers aiming to optimize urban regeneration tax incentives and align them with sustainable development goals. The research contributes valuable insights for policymakers aiming to optimize urban regeneration tax incentives and align them with sustainable development goals, as well as practitioners and researchers who are interested in optimizing strategies for sustainable urban development in the contemporary landscape. As the global discourse on sustainable practices continues to evolve, the role of tax incentives in fostering urban regeneration remains a critical component of the broader agenda for sustainable and inclusive development [19].

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Information Security in Universities Risk Management and Internal Audit

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Abstract. The digital transition brings new challenges to public administration. In the case of public higher education, henceforth referred to as universities, there is a responsibility in academic terms to transmit up-to-date knowledge in teaching and learning processes, but its internal services must ensure that the information produced and held is secure. The purpose of this study is therefore to demonstrate the relevance of information security and risk management, as well as the necessary adaptation of internal auditing to the paradigm shift in digital processes. In order to do this, it is necessary to know the main risks faced by the universities; in terms of cybersecurity, to know what measures universities have already implemented and which relevant measures are most relevant mitigating computer risks. With regard to internal audits, to understand whether universities use information technologies, more precisely artificial intelligence technologies. Through this study, it can be concluded that although some universities have identified direct information security situations in their risk management plan, there is still a lot of work to be done in the implementation of security requirements, and consequently, making them suitable for internal audits.

Keywords: Risk management · internal audit · universities · cybersecurity

1 Introduction

Information security at universities is full of challenges. Its scope must involve the entire institution, from governance, to operational to institutional support. Emerging technologies (such as 5G mobile communications; cloud computing; artificial intelligence (AI); Internet of Things (IoT); and quantum technologies) in terms of cybersecurity bring risks that must be managed. On the other hand, internal auditors must have adequate skills according to the processes that may be affected by these tools. However, the digital transition and the use of AI in internal auditing could be beneficial, automating and optimizing processes, making processes faster and more efficient.

The purpose of this study is to demonstrate the importance of information security and the role of risk management (RM) as well as internal auditing within universities, continuing the analysis that has been carried out on risk plans and complementing what is stipulated in legislation, particularly in terms of RM and information security. The aim is

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to provide information on the state of the art in terms of RM and its inherent relationship with information security and internal auditing in these entities, contributing to the knowledge of these institutional practices in terms of RM in universities.

The information obtained was through the public consultation made available on the websites of these entities, namely through their RM plans. A questionnaire was also sent out and the literature on these topics was reviewed.

This study shows that although most universities have a RM plan available on their websites, most of them are out of date in terms of the legal framework, particularly in terms of the scope of their entire organization and activity. It can be concluded that although some universities have included information security in their RM plan, it is still incipient, and there is a need for universities to have cybersecurity mechanisms to enable their institutional defense. In terms of conducting internal audits using emerging technologies, such as AI, there are still no associated practices.

2 Literature Review

Public administration is in the process of adapting to digital processes, which means that public services need human and material resources suited to the current technological reality. Public services, more specifically universities, have relevant data that makes RM an extremely important part of their organizational context. In this sense, it is essential that they have a consciously and systematically implemented RM.

In the case of universities, since they hold certain knowledge (students, training opportunities, employees, funding, research projects, among others), information security is essential in the day-to-day running of these organizations. Concepts such as digital transition and pedagogical innovation bring a new institutional paradigm that demonstrates the need for these entities to be properly updated in relation to technological issues. In this sense, universities must continue with information security and link the various technological processes in the academic context. However, the risks arising from the entry of new technologies are increasingly high, with internal auditing plays a key role in mitigating them.

2.1 Information Security in Universities and Internal Auditing

Most of the internal audits carried out at universities are inherent to their certifications, whether in relation to the environment; reconciling family and personal life; quality; social responsibility; or even information security. On the other hand, according to data from the Portuguese Accreditation Institute (IPAC) on companies certified in various systems, in 2022, only one public higher education institution was certified to the ISO 27001 standard - information security management system, making it compulsory to carry out internal audits of this system.

Different studies quantify the parameters associated with this security problem in different ways. Various reports [1–3] indicate that cybercrime will have increased by 25%−40% in each of the years 2020 and 2021.

At an individual level, adjusting to social, cultural and technological dynamics requires active digital participation on the part of citizens in the design of learning

experiences that prove essential for work situations. In this way, initiatives can balance the educational offer predetermined by higher education institutions [4]. The internal auditor must have diverse skills, presenting themselves as a digital native with a strong tendency towards innovation and intrinsic confidence in their work. All their duties must be carried out with excellence in terms of objectivity, independence, ethics and integrity. In this way, the transformation of internal auditing can be promoted, supported by new technologies and future processes in terms of information security and cybersecurity issues. In this respect, [5] there is a broad worldwide consensus that the three areas of greatest risk are firstly cybersecurity, secondly human capital and thirdly business continuity. Also in terms of internal audit effort perspectives, the areas of greatest effort in terms of risk levels for internal audit are remarkably similar [5]. In turn, [5] the survey presents sixteen risk categories, the highest in terms of risk level and highest in terms of internal audit time and effort – both now and three years in the future - is cybersecurity.

2.2 Risk Management and Cybersecurity in Universities

There has been an increase in computer attacks, and RM's position in relation to information security needs to be assessed in organizational terms. A more detailed analysis of this increase reveals not only a greater number, but a range of new attacks, exploiting technological developments at different levels, showing the sophistication and expertise of many of these attackers [6, 7]. The most relevant victims of cybersecurity incidents in Portugal during 2022 were the banking sector (mainly customers), education and science, technology and higher education, transport, health and the media. Public bodies suffered significant cyber-attacks, with Local Administration sub-sectors being the target of the highest number of incidents compared to other sectors [8].

Cybersecurity involves the development of actions, good practices, concepts, guidelines, tools, policies or technologies to be implemented by organizations in order to prevent possible computer attacks from third parties [9], namely techniques and behaviors applied by the individual in terms of their digital security [10].

When risky behaviors are applied, individuals experience a cyber-attack [11]. When a person goes through this experience, with the intention of violating their personal information system, they may change their behavior in relation to their digital security [12]. In this sense, they consider that prevention is necessary in order to detect, combat and avoid the effects of cybercrime, with a focus on technological development and user training being a path to consider [13], namely paying attention to cybersecurity issues, which is defined as the set of preventive measures and actions, monitoring, detection, reaction, analysis and correction aimed at maintaining the desired state of security, guaranteeing the confidentiality, integrity, availability and non-repudiation of information, networks and information systems in cyberspace and the people who interact with them [14].

As far as the public sector is concerned, it tends to follow the changes inherent to it, being determined by changes in regulation, thus allowing it to adjust to the changes that have occurred in public administration [15]. In turn, public sector governance includes the policies and procedures used to direct an entity's activities towards achieving its objectives in a responsible and ethical manner, thus reducing the risk of corruption [16]. Regarding universities, in a study on cybersecurity in higher education, it was

found that 246 courses/cycles of study are taught in public and private university and polytechnic educational institutions [4]. In terms of characterizing the courses and study cycles with cybersecurity and information security content in higher education, of the 246 courses/study cycles identified in the area of Computer Science, there are 109 that contain UC and/or content directly related to cybersecurity and/or computer security in their study plans. In terms of their distribution by course/study cycle of study, we have a total of 37 CTeSP, 36 Bachelor's degrees, 33 Master's degrees and 3 PhDs [4], which is in line with the need to promote advanced technical training in cyberspace security in university and polytechnic higher education, in order to meet the national needs for professionals in the sector [17].

Since 2009 (through the CPC recommendation) public universities have been required to have risk prevention mechanisms. Decree-Law no. 109-E/2021 reinforces this situation since the risks must cover the entire organization and activity, as well as carrying out internal audits to verify compliance. In turn, Law 46/2018 establishes the legal framework for cyberspace security, aimed at ensuring a high common level of security of networks and information systems throughout the European Union, and Decree-Law No. 65/2021, of June 30, which regulates the Legal Framework for Cyberspace Security, addresses the concerns and obligations in terms of information security for these entities.

In short, there is a need for these organizations to have mechanisms, such as internal auditing, that support security and cybersecurity and, consequently, what results from digital issues in terms of emerging technologies.

3 Methodology

In terms of methodology, following the literature review, the content of the universities' RM plans and the areas they cover were analyzed. Subsequently, a questionnaire survey was sent to all public higher education institutions (hereinafter referred to as universities), according to the information available on the *website* of the Directorate General for Higher Education, in order to assess these entities have identified risks associated with the areas of information technology and carry out internal auditing. The questionnaire was structured in three parts: characterization of the entity; risks and cybersecurity at university; internal audit.

4 Presentation and Discussion of Results

The analysis of university *websistes* showed that 75% of them had MR plans, 37% corresponded to university higher education and 63% to polytechnic higher education. In turn, only 44% of these institutions have contemplated and identified risks associated with technological areas, having considered issues inherent to data protection and security in information systems and consequently cybersecurity.

The questionnaire was sent to public universities. After submitting the responses, a total of 6 valid responses were obtained, corresponding to a response rate of approximately 17.6%, of which around 66.7% are from polytechnic higher education and 33.3% from university education. In terms of size, 33.3% are institutions with up to 5,000 students, while 66.7% are between 5,000 and 10,000 students.

The main risks faced by universities, as shown in Fig. 1, are as follows: difficulty in obtaining revenue and access to financial markets and lack of technical knowledge of new processes, with 33.3% of the responses. 50% pointed to threats associated with the macroeconomic context. With 66.7% of threats associated with the geopolitical context. 16.7% answered lack of compliance with regulatory standards. However, 100% pointed to threats associated with cybersecurity as the most significant risk, in line with the IIA 2024 study, which points to "Cybersecurity" as the main risk that organizations face today and will face in 3 years' time [5].

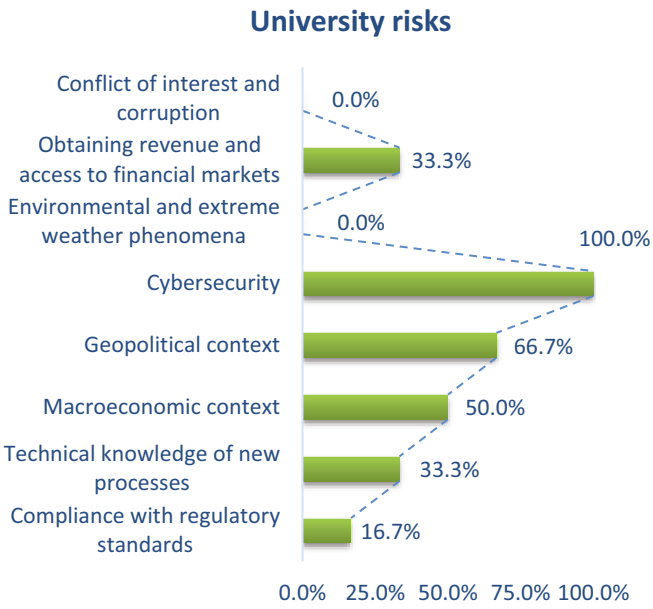

Fig. 1. Main risks facing universities

When asked whether the university has taken any action to mitigate the identified risks, 83.3% said yes, while 16.7% did not. These results are in line with the fact that information security at universities is included in their RM plans [18].

With regard to the measures already in place (Fig. 2), the majority indicated that they have appointed a permanent point of contact and a security officer and carry out a risk analysis of all the assets that guarantee the continued operation of the networks and information systems they use. Drawing up and updating an inventory of all essential assets was answered in 80% of cases. With regard to drawing up and updating a security plan, identifying measures and organizations to manage the risks identified; drawing up an annual report; implementing the means and procedures necessary for detecting, assessing the impact and reporting incidents with a significant or substantial impact, 40% of the respondents said that their university already had measures in place.

Although universities already have some measures in place, 50% of cases indicated that they had been the target of computer attacks (16.7% don't know and 33.3% haven't),

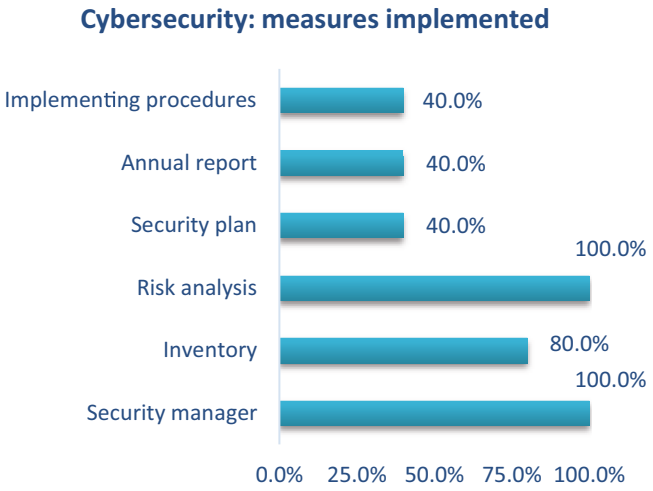

Fig. 2. Measures implemented by universities in terms of cybersecurity

of which 75% responded replied that it was possible to recover the information (25% don't know), and no personal data was accessed.

In terms of the most relevant measures to mitigate IT risks, the most important were access policies (100%) and promotion of equipment maintenance (83.3%). Network diagrams and restricted access for employees, especially those working remotely (66.7%). The support of the internal audit was answered by with 50%.

With regard to internal auditing, 60% said they had this service and that it was carried out annually and biannually and every six months. When asked if they have various systems, including financial systems, were automated, 83.3% said yes and 16.7% said no. On the other hand, if internal audits are carried out using information technology, 50% didn't know or didn't answer this question, 33.3% said no and 16.7% said yes.

The artificial intelligence technologies (Voice Recognition; Image Recognition; Robotic Process Automation; Machine Learning; Process Mining; Computer Vision; Artificial Neural Networks; Deep Learning; Natural Language Processing; Virtual Agents) that internal auditors are familiar with and how often they use them in their audit work were answered by the majority of universities as "never". "Image Recognition", "Natural Language Processing" and "Virtual Agents" are rarely used and occasionally "Process Mining".

5 Conclusions

Universities must adapt to the changes that are emerging, exploring all the resources they have available, improving the way they are managed in the face of the countless amounts of data generated by different technologies. In turn, with the arrival of emerging technologies in the academic context, the digital transition and pedagogical innovation will be able to automate and monitor processes more effectively, but it also brings risks. These entities therefore have to adapt, but also identify the risks that these changes

bring and that are associated with them, specifically those directly linked to information security. On the other hand, audits must check that these situations are compliant and report back to management in order to help make the right decisions.

Public higher education, whether for legal reasons (Code of Administrative Procedure and Public Contracts), or for the personal data of students, workers or scientific research, are examples of the relevance of digital security issues. However, mechanisms are needed, through electronic means, to ensure the vulnerabilities that arise in these institutions from the increased use of technology.

In terms of mechanisms associated with information security, the public information on university *websites* shows that some public higher education institutions have included information security in their RM plan. In turn, one is ISO 27001 certified, which demonstrates an effective concern with these issues. On the other hand, given the growing amount of data associated with these organizations, it is necessary for internal auditors to keep up to date with emerging technologies and, consequently, support cybersecurity issues.

The internal audits carried out in public higher education must be appropriate to the current context, more precisely in relation to the digital transition and support in terms of mitigating identified risks, also supporting information security issues.

In terms of limitations, the low response rate to the questionnaire survey limits the conclusions. On the other hand, future proposals suggest continuing this study by relating information security to strategic indicators and the support that emerging technologies can bring to organizational performance and improvement. Likewise, in conjunction with the size of universities, it would be useful to assess in terms of the certification of digital maturity (which is one of the measures in the Digital Transition Action Plan to promote the digital transformation of the economy), whereby universities could be certified in four dimensions: Sustainability, Cybersecurity, Privacy and Protection of Personal Data and Accessibility.

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Management Accounting and Digital Transformation in the Government Sector: A Science Mapping Review

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Abstract. This study used a science mapping approach to provide an overview of the scientific production of digital transformation in the government sector from the management accounting perspective. It considered a bibliographic sample of 127 articles extracted from Scopus and WoS. Results showed that almost 69% of the articles analyzed were published in the last five years. This growth in scientific production is mainly due to technological innovations, the requirement for real-time information, legal changes and accounting standards, efficiency and cost control, and sustainability and social responsibility concerns. The conceptual structure of this sample was grouped into six clusters: management control; auditing and participatory budgeting; public procurement control; blockchain in the government budget control; digital government service and social media; and public financial management reform.

Keywords: management accounting · digital transformation · government sector · science mapping

1 Introduction

Digital transformation in the government sector provides effective, flexible, and open management systems, revolutionizes decision-making, optimizes bureaucratic procedures, contributes to improving citizens' quality of life, and ensures sustainable development [1]. Advances in public accounting and management accounting resulting from digital transformation can also improve the quality of government institutions and the services they provide to society. According to [2], the quality of institutions has proved to be an essential factor in explaining people's life satisfaction and happiness. In addition, it may improve citizens' participation in the budget decision-making process and strengthen democracy. Management accounting may help with this process. Considering this, public sector organizations worldwide have implemented substantial transformations over the past two decades and introduced new information technology-enabled

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management control systems [3]. In line with this, technological resources, such as artificial intelligence, big data analysis, and e-governance are becoming essential tools for achieving efficiency and accountability in modern public governance [1]. These advancements tend to make public organizations more efficient and citizen-focused [4].

In this context, scientific production on digital transformation in the government sector from the management accounting perspective increased considerably in recent years. Such discussions have been developed under multiple perspectives, including big data, digitization and accounting transformation, business intelligence and analytics (BI&A) tools, management control systems (MCS), Artificial Intelligence (A.I.), Machine Learning (M.L.), and blockchain. Despite the considerable growth in academic research in this field, there are still significant research gaps. For instance, as pointed out by [5], there is a need for empirical evidence to support the assumptions made about the advantages of AI in the public sector.

Considering this and aiming to subsidize future empirical research, this study's objective was to map the central current academic debates by applying science mapping analysis to a bibliographic sample of (127) articles extracted from Scopus and Web of Science (WoS) to understand the main aspects of scientific production and map its conceptual structure. This study approach, including the term co-occurrence analysis based on text-mining techniques, is relevant, especially in the context of growing academic production and constant and rapid digital transformations, considering that it provides visualization of the relationships between topics and areas of study through the trends topics identification and analysis of research clusters, identifying gaps and themes little explored, inspiring new studies and contributing to the knowledge advancement. Additionally, this multidisciplinary perspective between digital transformation in the public sector and management accounting may provide insights for public managers and policymakers that can base their decisions on scientific evidence as support for formulating public policies and strategies. This study is structured as follows: After this introduction, the next section presents the methods, research questions and research strategies. Then, the results analysis and discussion, followed by the conclusion section.

2 Methods

This study adopted systematic literature review protocols, bibliometric analysis, and science mapping to explore digital transformation in the government sector under the perspective of management accounting-related studies indexed on Scopus and the WoS.

2.1 Research Strategies

The research strategies applied included a longitudinal analysis of a bibliographic sample the PRISMA statement [6], bibliometric analysis, and science mapping [7–10] to answer the following research questions:

Research Question 1: What are the main aspects of scientific production related to digital transformation in the government sector under the perspective of management accounting-related studies? RQ1 aims to provide an overview of the scientific production based on bibliometric performance analysis: annual scientific production, journals, countries, and authors.

Research Question 2: What are the main aspects of the conceptual structure of the bibliographic sample related to digital transformation in the government sector under the perspective of management accounting-related studies? RQ2 aims to understand this knowledge area through science mapping techniques using term co-occurrence analysis.

2.2 Sample Selection Process and Workflow

Four main analysis stages were developed to answer the research questions, as depicted in Fig. 1.

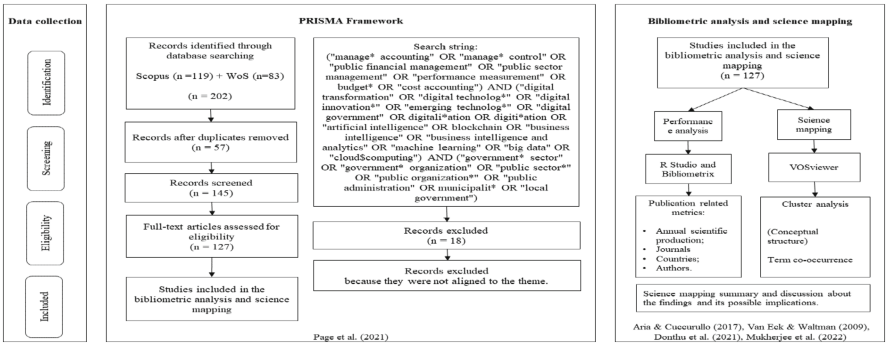

Fig. 1. Science mapping workflow.

The first phase included PRISMA statement protocol. In this step, the following terms were applied to the Scopus and WoS: (“manage* accounting” OR “manage* control” OR “public financial management” OR “public sector management” OR “performance measurement” OR budget* OR “cost accounting”) AND (“digital transformation” OR “digital technolog*” OR “digital innovation*” OR “emerging technolog*” OR “digital government” OR digitali*ation OR digiti*ation OR “artificial intelligence” OR blockchain OR “business intelligence” OR “business intelligence and analytics” OR “machine learning” OR “big data” OR “cloud$computing”) AND (“government* sector” OR “government* organization” OR “public sector*” OR “public organization*” OR “public administration” OR municipalit* OR “local government”). The strategy for combining these multiple terms was defined based on this study initial exploratory analysis, in which multiple terms, approaches, and perspectives were identified, involving studies related to the digital transformation in the government sector and management accounting. Other query string strategies was previously tested. However, this combination returned the most significant number of articles that were most directly related to the purpose of this research. Based on this strategy, and considering filters applied in both databases for document type “Article”, and language “English”, resulted in (119) articles published in the Scopus, and (83) in the WoS, from 2004 to 2024. The next step consisted in export both bibliographic metadata files and merge them. In this process, (57) duplicated items were eliminated, resulting in a sample of (145) articles for analysis. Then, after reading titles and abstracts, (18) articles were excluded, considering

they were not aligned with the theme. Following this, bibliometric performance analysis and science mapping techniques were applyied using the Bibliometrix [8] and the VOSviewer [7].

3 Results

3.1 Bibliometric Performance Analysis (RQ1)

Annual scientific production: This analysis revealed that almost 69% of the articles analyzed were published in the last five years. Figure 2 illustrates the annual scientific production of the (127) articles, which shows this growth in recent years.

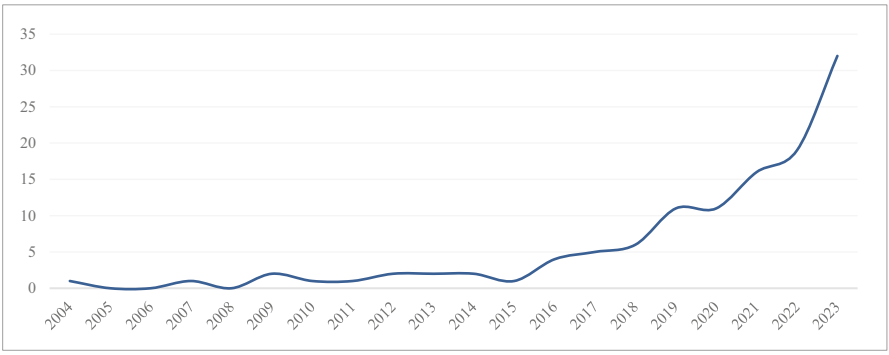

Fig. 2. Annual scientific production

The highest annual growth rates occurred in 2021 and 2023, an increase of 68.4% and 45.5%, respectively, compared to the previous years. This was mainly influenced by discussions related to the pandemic crises combined with discussions related to technological advances and the digital transformation necessary to provide quality public services. In general, according to the literature, this growth in scientific production regarding digital transformation in the government sector involving management accounting may be explained due to technological innovations, requirement for real-time information, legal changes, and accounting standards, need for efficiency and cost control, and the growth in sustainability and social responsibility concerns.

Journals: This analysis revealed that the (127) articles were published in (108) different scientific journals. This diversity of journals indicates the multidisciplinary perspectives and discussions related to digital transformation in the government sector and its implication in management accounting under this sample analysis. Most of the analysed articles were published in public adminsitration, accounting, economic, and information system related journals. Table 1 presents the proportion of such journals, including their impact factor according to the Scimago and the Clarivate metrics. Additionally, to broaden the spectrum of analysis in relation to this other journal evaluation, the respective Academic Journal Guide (AJG) ranking, a specific journal measurement for business and management-related fields, was also provided.

Table 1. Journals.

Sources	2022 SJR	SJR Quartile	2022 JIF	JIF Quartile	AJG 2021	Articles	(%)
Public Policy and Administration	0.9	Q1	3.1	Q2	2	3	2.4%
Accounting, Auditing and Accountability Journal	1.7	Q1	4.2	Q2	3	2	1.6%
Ad Alta-Journal of Interdisciplinary Research	*	*	0.7	*	*	2	1.6%
Baltic Journal of Economic Studies	*	*	0.5	*	*	2	1.6%
Business Process Management Journal	0.9	Q1	4.1	Q3	2	2	1.6%
Economic Alternatives	0.1	Q4	*	*	*	2	1.6%
Electronic Journal of Information Systems in Developing Countries	0.4	Q3	1.3	*	*	2	1.6%
Financial Accountability and Management	0.6	Q1	2.2	*	3	2	1.6%
Government Information Quarterly	2.3	Q1	7.8	Q1	3	2	1.6%
IEEE Access	0.9	Q1	3.9	Q2	*	2	1.6%

The analysis revealed that the Public Policy and Administration published the most articles in this sample (3). Followed by the Accounting, Auditing and Accountability Journal (2). These Journals are considered relevant in the public administration and accounting field.

Countries: The adoption of digital technologies has brought significant changes to public administration across many countries [4] and it has inspired scientific production around the world. In this sense and considering the importance of mapping scientific production in the international context, the analysis of the authors affiliation countries' frequency distribution revealed that the authors of the (127) articles in this sample are affiliated with institutions in 50 different countries. Figure 3 shows the top 20 authors' affilliation countries under this sample analysis. Results showed that the top 10 most

relevant countries are USA (9.2%), Ukraine (7.3%), UK (6.3%), Italy (4.4%), China (4.1%), Germany (4.1%), Australia (3.8%), Brazil (3.8%), Spain (3.8%), and Finland (3.5%). The authors' affilliation countries of these countries corresponds to 50.3% of the analyzed sample. If considered together, these countries correspond to 50.3% of the total authors' affiliation nations of this sample.

From the perspective of the citation number by country, Egypt stands out, with a total citation of (163), in the article by Suzanna ElMassah, in Digital transformation and localizing the Sustainable Development Goals (SDGS) [7]. Then, USA and China, with 94 and 82 total citations, respectively. Revealing not only the supremacy and interest of these countries in terms of scientific production, but also their influence on the knowledge construction and discussions about digital transformation within the scope of the government sector.

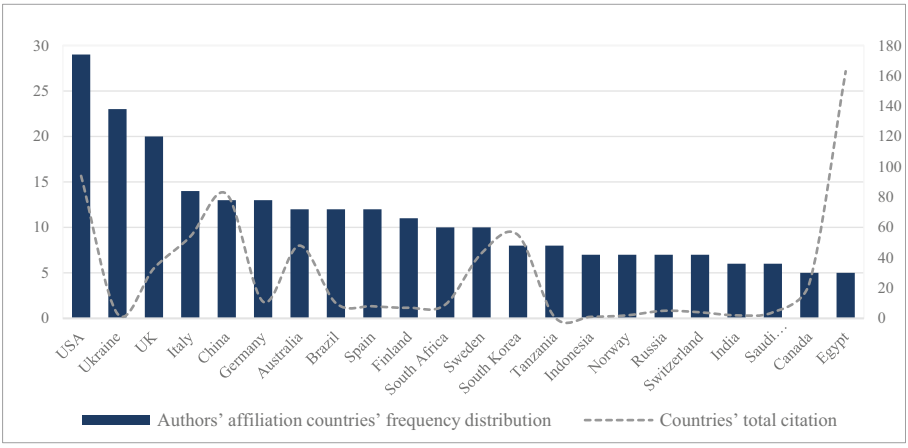

Fig. 3. Countries

Authors: The most productive authors in this sample were André Lino, Sumaya Abbas, Moongie Kim, and Sudhamshu Addanki, three articles each. These authors focused mainly on mandatory digital transformation, digital infrastructure, machine learning issues. Figure 4 shows the top 20 most productive authors combined with total citation.

André Lino developed recent studies on accountants' attitudes concerning the mandatory digital transformation, and issues relating to the impact of local governments' audit organizations' data collection systems and their digital infrastructures. Sumaya Abbas proposed a machine learning approach in a management engineering system to reduce the environmental, economic, and societal impacts of municipal waste. Moongie Kim proposed strategies of advanced use of data infrastructure for local government analysis, including it cost-benefit analysis to support decisions related to the financial feasibility. Within the sample, the most cited article was developed by Suzanna ElMassah, in Digital transformation and localizing the Sustainable Development Goals (SDGS) [11], in which the author highlights the importance of digital transformation in fostering sustainable development strategies at the local level.

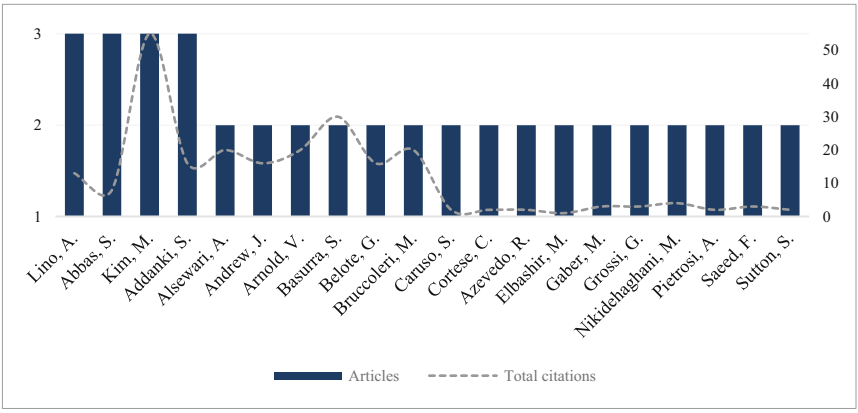

Fig. 4. Authors

3.2 Science Mapping (RQ2)

The text-mining functionality of VOSviewer was applied to map the conceptual structure. This function supports generating term maps based on a corpus of documents that visualizes the conceptual structure of a field [7]. This analysis aimed to visualize the main lines of research based on the relatedness and co-occurrence of the most relevant terms within the titles and abstracts of these (127) articles. For this objective, a binary method, and the minimum number of one occurrence of each term were applied in the software. Considering these parameters, the 2,510 most relevant terms were initially selected, resulting in a sample of 446 most relevant terms after four cleaning stages process to exclude terms not directly related to the topic. This set of most relevant terms was grouped in six clusters. Figure 5 presents these six clusters, revealing the six main research streams within the studies about digital transformation in the government sector from the management accounting perspective. Therefore, under such perspective, the science mapping analysis revealed that the conceptual structure of this subject area may be categorized into the following main study lines, including management control; auditing and participatory budgeting; public procurement control; blockchain in the government budget control; digital government service and social media; and digital innovation and public financial management reform. Table 2 presents the most relevant terms related to each cluster.

In addition to mapping the conceptual structure, this cluster analysis can offer insights into research gaps that may arise from the combination of examined qualitative and quantitative perspectives to understand the terms' relevance and interrelationship. The qualitative perspective involves prior knowledge of the topic and identifying the term-related document to ensure an effective contextual analysis. The quantitative perspective comprises the analysis of the map's structure and attributes, which include the relative position of terms in the map, the weight of the frequency of occurrences, the links, and the total link strength of a term. In this sense, the following paragraphs provide an overview of each cluster's conceptual structure, emphasizing their main themes, including some

Table 2. Clusters.

Cluster	Cluster name	Most relevant terms
Cluster 1 – Red (106 terms)	Technological development and management control	Cloud computing; public budget; machine learning; performance measurement system; technological development; decision making process; management control; health sector; economic security; big data analytic
Cluster 2 – Green (91 terms)	Digitalisation and government auditing and participatory budgeting	Digitalisation; sustainable development goal; data collection system; government auditing; participatory budgeting; web application; machine learning model; citizen expectation; forecasting; budget execution; digital infrastructure
Cluster 3 – Blue (75 terms)	Public procurement system control	Control; responsibility; performance indicator; public procurement; corruption; e-government; risk management; financial control; internal financial control; budgetary fund
Cluster 4 – Yellow (68 terms)	Blockchain in the government budget control	Blockchain; compliance; advanced digital technology; federal government; budgetary control; budget transparency; interoperability; consortium blockchain budgetary control system; consortium blockchain monitoring system; consortium blockchain technology

(*continued*)

identified gaps, how they can be explored, potential methodologies for conducting future research, and possible contributions such studies may offer.

Cluster 1 is the largest, and it also presents diverse approaches and perspectives regarding the technological development in government administration and management

Table 2. (*continued*)

Cluster	Cluster name	Most relevant terms
Cluster 5 – Purple (49 terms)	Digital government service and social media	Digital government service; public service performance; social media; tweet; performance evaluation; public sector budgeting; administrative system; fiscal decentralization; governments digital transition
Cluster 6 – Blue turquoise (42 terms)	Digital innovation and public financial management reform	Welfare system; digital innovation; accounting practice; financial information; data governance; local authority; public financial management reform; new algorithmic accountability; public sector management system; fiscal transparency

control [12], including the decision-making process and performance measurement systems [3]. From the perspective of digital technology terminologies, several terms were explored in this cluster, such as cloud computing, artificial intelligence, machine learning, big data analytics and business intelligence. Discussions related to environmental issues are also a subtheme within this cluster. Some of them are connected to public services, such as public transportation [13] and municipal waste management [14], and focus on managing public financial and non-financial resources for environmental sustainability.

The terms analysis in this cluster reveals discussions on digital transformations and their potential application in management accounting in the public sector. Gaps that can be highlighted refers to empirical studies that can be conducted to explore the success factor using the performance measurement technique from business intelligence [15], and studies related to advanced analytics from big data to optimise financial planning and government resource allocation. Case studies on these matters could contribute to improve debates regarding the accuracy of financial analysis, including forecasts for optimised allocation of public resources.

It is worth highlighting some research gaps that can be associated with the terms cloud computing and machine learning. Regarding cloud computing, although this term is among the most frequent within this cluster, its specific application in management accounting in the public sector requires further empirical studies, including research on how cloud computing can help to improve the accessibility and security of accounting data in local governments, as suggested by [16]. As a potential methodology, such studies could use case studies or focus groups to explore issues related to risk assessment

and security models in cloud computing platforms contributing to increased awareness, security, and efficiency of access to accounting data.

In general, terms in cluster 2 are associated with articles discussing digitalization, sustainable development goal, government auditing, and participatory budgeting. Some approaches include discussions on how the use of digital technology in public sector audits affects budget planning in local governments [17]. Debates concerning sustainable development goal is relevant in this cluster, including discussions on how local governments responded to the pandemic through digital transformation [18].

More studies should be developed on applying environmental data in management accounting for government decision-making and the need for better alignment and practical integration of Sustainable Development Goals (SDGs). It could include the impact of environmental databases on management accounting to investigate how they can be more effectively integrated into accounting systems to promote sustainable practices.

Case studies could be applied to analyze the integration of this data and its impact on government decisions. Such academic discussions can increase awareness of more sustainable management practices and fulfil global environmental objectives. Additionally, as mentioned by [11], future research should include significant elements of social inclusion and service delivery results and elaborate on a measurable indicator for assessing digital transformation's effects on the local SDGs.

The main terms in cluster 3 are associated with articles that discuss the use of artificial intelligence [19] to financial control and responsibility, mainly regarding public procurement system control [20, 21] to avoid corruption, provide accurate decision, and better outcome and efficiency in the government budgetary process. Additionally, in this cluster issues related to e-government were also discussed. This debate is important because it allows for better government services, greater citizen access to information, and more efficient government management, according to [10].

In this context, one of the gaps that can be mentioned is the need to explore how digital technologies can be used to automate and strengthen compliance processes and financial control in the public sector, as highlighted by [22]. In this sense, studies applying comparative analysis of technologies and implementation and their impact assessment may enrich debates, for instance, on increasing efficiency and reducing corruption and fraud in the government sector. In addition, as mentioned by [23], digital technologies are considered a modern tool for improving the administration of the procedure of internal financial control of expenditures of budgetary institutions. Considering this, another possibility for future research could be related to optimising risk management processes, such as integrating risk prediction and assessment systems with governance platforms using emerging technologies. Case studies on risk analysis could contribute to debates on more accurate risk prediction and more agile responses.

Cluster 4 addresses issues related to the application of blockchain technology in the budget transparency and democratic control over the use of public resources [24–26]. Some study explores the use of tokenization in blockchain technology to improve the execution of public expenditure on governmental investments [24], including discussions related to the consortium blockchain monitoring and evaluation system to monitor budget projects, processes, and transactions [25].

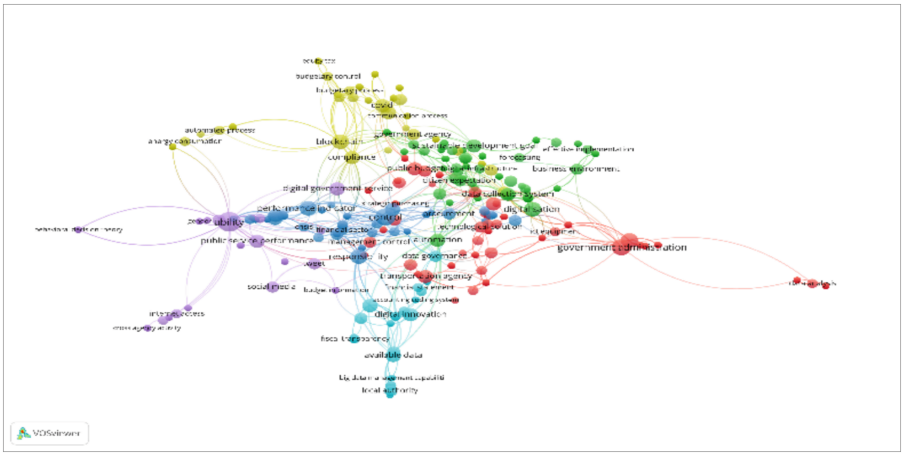

Fig. 5. Term co-occurrence analysis

In this context, more studies should be conducted on how blockchain specifically affects management accounting practices in the public sector. As highlighted by [25], studies in the public sector have been slower than those in other sectors in investigating blockchain technology. Considering this, empirical studies on implementing blockchain in government institutions, performance impact analysis, and tax compliance could shed light on how to improve accountability and transparency in government processes and reduce fraud and corruption.

In cluster 5 some debates related to the public services management, including the impact of digital technologies and internet access, mainly thorough social media [27], as possibility to public service performance evaluation by citizens. Such discussions include issues ranging from administrative system [28] to public sector budgeting [27] to improve digital government service efficiency.

However, according to [28], empirical studies on digital services are scarce, principally for service performance evaluation. In this sense, empirical studies that address the implementation of digital technologies in specific accounting practices in the public sector and how this improves performance and strategies should be investigated more. Regression analysis and comparative case studies between different levels of government can contribute to debates to improve efficiency, accuracy, and government accounting practices.

The main terms in cluster 6 are associated with articles that discuss the process of digital innovation and public financial management reform [29] to increase fiscal transparency and combat fraud, mainly related to accountability mechanisms to fraud detection in social welfare system [29, 30]. In addition, some discussion related to the public financial management reform [31] also includes changing in accounting practice [30] and in the accountant's posture [29], highlighting the importance in analytics capabilities [32] to the best use of digital technologies, cost structure and better decision making to improve economic efficiency.

For this reason, it is vital to have well-equipped employees with digital skills, as they are essential for adopting and effectively using digital technologies in accounting and financial management. Thus, more studies should be conducted on digital literacy in public administration, in detail, on how digital skills are being developed among public employees within the scope of public accounting and management accounting. Research dedicated to exploring effective methods of training and developing digital skills in management accounting can shed light on how to improve management accountants' skills to maximize the benefits of digital transformations in the public sector.

4 Conclusions

This study applied science mapping techniques to explore the scientific production of digital transformation in the government sector from the management accounting perspective, sample of (127) articles indexed in Scopus and WoS. The most discussed digital technology terminologies include cloud computing, artificial intelligence, machine learning, big data analytics, business intelligence, and blockchain. According to the literature, the digital transformation in government sector aligned with management accounting practices aims to provide operational efficiency, improved decision-making, security in transactions, more transparent and responsible governance. Additionally, it improves the government service quality an increase in citizen participation, such as in the budget participation process.

Regarding RQ1, the analysis revealed that almost 69% of the articles analyzed were published in the last five years, due to technological innovations, requirement for real-time information, legal changes, and accounting standards, need for efficiency and cost control, and the growth in sustainability and social responsibility concerns. The most relevant journals were *Public Policy and Administration* (3) and *Accounting, Auditing and Accountability Journal* (2). The most productive authors within this sample developed studies related to mandatory digital transformation, digital infrastructure, machine learning issues. The most cited article was *Digital transformation and localizing the Sustainable Development Goals (SDGS)* about the importance of digital transformation in fostering sustainable development strategies at the local level.

The scientific mapping regarding RQ2 revealed that the conceptual structure of this set of articles may be grouped into six main research streams: including management control; auditing and participatory budgeting; public procurement control; blockchain in the government budget control; digital government service and social media; and digital innovation and public financial management reform. Through this perspective, it was possible to identify some research gaps. Considering this, some themes are suggested as future research. First, more empirical studies should be developed to substantiate the approaches and respective benefits of the practical application of artificial intelligence and blockchain technology in management accounting in the government sector.

Second, studies should be conducted to understand how digital transformation based on AI technology and advances in management accounting methods can increasingly contribute to improving social and environmental sustainability. Third, it is crucial to research how accounting courses offered in universities can be modified to encourage the development of statistical and technical skills necessary for future management

accountants to effectively leverage the potential of digital technologies such as AI and blockchain in government sector.

In this study there are some limitations about research strategies and methods. Regarding this, future research using other search term strategies, other bibliographic databases, and different science mapping techniques may lead to different findings.

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Leveraging Customer Audit: A Decision Support Dashboard

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Abstract. In the contemporary digital landscape, businesses harness formidable technological prowess to engage directly with customers and amass vast troves of consumer data. However, amidst this wealth of information, a critical gap persists in translating data into actionable insights that fuel business success. Traditional metrics fall short in capturing the intricate nuances of customer behavior and preferences, necessitating a shift towards more customer-base audit report systems. Drawing upon essential inquiries delineated in existing literature, this research aims to address pivotal questions integral to constructing an effective customer-base audit report. These inquiries encompass identifying customer segments, discerning differential value among customers, assessing revenue concentration, and forecasting customer retention. Through an exploration of data-driven methodologies and the development of a decision support dashboard, this research endeavors to furnish pragmatic guidance for organizations seeking to fortify their customer-centric reporting capabilities.

Keywords: Customer · Customer-base · Audit · Analytics · KPI · Dashboard · CLV

1 Introduction

In today's digital age, companies wield unprecedented technological capabilities that empower them to gather customer information and engage directly with their audience. Gone are the days of mass marketing, where generic messages were broadcast to an undifferentiated crowd. Instead, businesses now have a wealth of options to tailor their approach and connect with customers on a more personal level [1, 2].

However, despite these advancements, there remains a critical problem and gap in the current landscape of audit reporting. While companies have access to vast amounts of data, they often struggle to translate it into actionable insights that drive business outcomes. The traditional metrics used to measure success, such as revenue and sales volume, fail to capture the nuances of customer behavior and preferences [1–3].

In response to this challenge, there are a subset of questions that any customer-base audit report should address [4]: (1) Who are the customers your firm has? (2) How do

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these customers differ in terms of their value to the firm? (3) How many customers accounted for half of your revenue last year? (4) How many customers who bought your products last year can be expected to buy from you this year?

Thus, the objective of this research is to bridge the gap between data and actionable insights by exploring how companies can leverage data-driven approaches to answer these questions and build a robust audit reporting system. By embracing customer-centric strategies (that is, to cultivate their customers by serving them and their segments) and rethinking traditional metrics, organizations can thrive in an era where personalized experiences reign supreme [1]. Through a comprehensive analysis of these questions and the development of a decision support dashboard, this research aims to provide practical guidance for companies seeking to enhance their customer-centric reporting capabilities and drive sustainable growth.

2 Understanding Dashboards

A dashboard is an information management tool that analyzes, selects, and presents key performance indicators (KPIs) informing managers about the company's situation in a simple and visual manner. Visual refers to converting complex data into easily understandable and accessible information [5]. With a dashboard, real-time monitoring and improvement of the company's performance can be achieved, thereby reducing the time between analysis and reaction. Generally, they assist in strategy definition, planning, and goal control [6].

A dashboard must consider five characteristics to be developed correctly [7]: (1) Synergy: it should present a visually efficient and ergonomic design to synthesize various information into a single source; (2) Accuracy: the gathered information must be reliable; (3) Flexibility: the initial structure should be able to adapt to changes the company may undergo; (4) Display: data should be visible in real-time, allowing decisions to be made based on the most current data; (5) Accessibility: information should be available at any time.

When constructing a dashboard, the chosen presentation format should be considered. Graphs are used to display forecast data or for comparison and pattern recognition. In contrast, tables are more suitable for presenting information to analytical individuals [5].

There are three types of Dashboards, as each tends to communicate to different functions within the company [8]: (1) Operational Dashboards: Supervisors can track operational processes; (2) Tactical Dashboards: Provide information for each department of the company; (3) Strategic Dashboards: Monitor the company's performance in relation to the initially proposed objective.

There are different purposes for dashboards: monitoring, consistency, planning, and communication. Monitoring aims to evaluate metrics daily, resulting in an action plan with corrective measures. Consistency involves aligning the company's processes and measures across all departments. When the purpose is planning, the goal is to use analyzed data to plan the best strategy for the company to move towards its objective [5].

Ultimately, the dashboard's main purpose is to communicate organization information to its stakeholders, enabling managers to make decisions based on viable information [5].

3 Understanding KPIs

KPIs are an important tool for measuring and evaluating real company performance. Their use allows for defining corrective measures in its management to achieve the predefined objectives [8]. Moreover, these indicators help translate strategic objectives into long-term goals. To adequately assess the company, one of the good practices to consider is the selection of clear and achievable KPIs [9].

KPIs assist managers in making decisions based on assessments of the company's progress towards a specific goal. They enable the detection of whether it is moving in the right direction and any failures so that they can be corrected in time for the company to reach the objective [10]. There are various types of KPIs, examples of which include strategic KPIs, providing high-level information about organizational performance, and operational KPIs, measuring organizations' day-to-day performance by departments [11].

KPIs, which comprise an effective evaluation system, should have the following characteristics [12]: (1) The indicators used should consider whether they are suitable for the sector in question; (2) They should cover aspects of the past, present, and future; (3) They should include indicators that encompass all parts of the company; (4) They should be able to adjust according to the changes the organization may undergo.

KPIs should be represented by values to enable comparison both within the company and with those of other companies. There should always be target values, allowing the company to gauge its performance: whether it is above, below, or close to achieving the set objective. Graphs should be created to help managers better interpret the information and, consequently, identify problem areas and key success factors more easily [9].

4 Customer Analytics

The fundamental purpose of a business is to create and retain customers [13]. However, despite this understanding, many managers fail to prioritize customer relationships [14]. In fact, loyalty leaders significantly outperform their peers [14], emphasizing the potential of customer-centric strategies for business growth.

The roots of the issue traces back to the 1890s [14], exacerbated by Milton Friedman's shareholder primacy introduced in 1970 [15]. The prioritization of quarterly earnings over customer relationships has persisted due to limited reporting on customer value, lacking capabilities, and traditional organizational structures [14].

However, a paradigm shift was proposed, advocating for an "age of customer capitalism" where prioritizing customers creates greater value for shareholders [16]. The emergence of new accounting tools and a shift in organizational structures are identified as essential elements in realizing this vision. [14].

4.1 The Importance of Customer Analytics

The importance of constantly monitoring customers comes from the increasing recognition that traditional financial metrics alone may not fully capture the complexities and dynamics of contemporary business environments, where customer relationships play a pivotal role in long-term sustainability [1].

Due to the evolving nature of businesses, where customer metrics (e.g., Customer Lifetime Value (CLV), retention, satisfaction) are crucial drivers of success [3], the relevance of this thematic lies in including customer KPIs through a constant monitoring via dashboard, besides only the traditional financial ones. Providing stakeholders with a more comprehensive understanding of organizational performance.

In fact, recent reports from Bain and Company [3] reveal that businesses have placed greater focus on discovering and cultivating connections with their most valued customers as more executives and investors come to understand that these clients are the ultimate source of business value. Executives should monitor customer value with the same care as they monitor other important assets like buildings, machinery, and inventory, considering how important it is [3].

Another study in this sense comes from McKinsey and Company, where they carried out a survey of 700 senior marketing and salespeople, to understand the current perception in companies regarding customer analytics and the impact they can have. In this study, McKinsey and Company highlight the importance of customer analytics for corporate success (Fig. 1). Despite a perceived decrease in importance among marketing and sales executives, the extensive use of customer analytics significantly impacts corporate performance. In fact, companies employing customer analytics comprehensively report outperforming competitors in terms of profit, sales, sales growth, and return on investment [17].

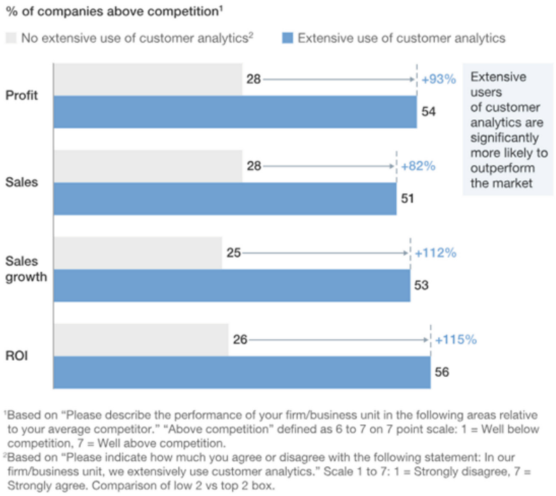


Fig. 1. Customer Analytics on Corporate Performance. Source: [17]

4.2 Customer-Base Audit

There is a core set of analytical procedures essential for executives aiming to grasp the vitality of their organization's revenue and profit dynamics, as well as the viability of their expansion strategies. Termed as the "customer-base audit" [4] this entails a methodical examination of the purchasing patterns exhibited by a company's customers, leveraging data sourced from its transactional infrastructure. And as previous mentioned, there are a subset of questions that any customer-base audit report should respond [4]:

Who are the customers your firm has? This question focuses on understanding who is buying your products. This is specially relevant in terms of marketing strategy.

How do these customers differ in terms of their value to the firm? Understanding the varying value that different customers bring to the firm is crucial for optimizing marketing strategies, resource allocation, and customer service efforts.

How many customers accounted for half of your revenue last year? This question provides insights into revenue concentration and helps identify the significance of key customers to the firm's financial performance.

How many customers who bought your products last year can be expected to buy from you this year? Forecasting customer retention and repurchase behavior is essential for revenue forecasting and resource planning.

To answer these questions is necessary a strong set of analysis and KPIs, as covers aspects of the past, present, and future.

4.3 Customer Dashboard

Given that immediate responses to such questions are not possible, particularly in predicting customer repurchases which necessitate the utilization of behavioral variables requiring months for calculation, this dashboard serves a different purpose compared to operational ones. Instead of being utilized on a daily basis, it is designed for higher-level reporting, typically spanning several months and targeted at upper echelons of management. In light of this context, a tactical dashboard emerges as the most appropriate choice for customer analysis purposes. It equips departments with insights into tactical processes associated with customer interactions, enabling tracking of diverse metrics such as CLV, the customer value pyramid, and customer transition states.

The accessibility of information on the tactical dashboard empowers departments to monitor these customer-related metrics, enabling them to identify trends and patterns.

5 Methodology

The case study is one of the largest fast-moving consumer goods (FMCG) retail companies in Portugal which, to date, has not yet developed an analysis of the customer besides the gross expenditure per purchase. The data is a transactional dataset with purchases made between years x and x-1, by a representative number of customers.

The solution consists in a dashboard, implemented in Power BI, that derives its data and automation from various streams within SPSS Modeler, enabling the calculation of a myriad of indicators and variables. To streamline analysis and prevent dashboard overload, a menu has been devised; this menu facilitates navigation between windows, each containing distinct sets of information. Within each window we have an answer to each question:

5.1 Customer KPIs and Analysis

In this case, to answer the questions previously mentioned, certain indicators were calculated, and analysis were implemented via dashboard that allow the construction of a customer analysis that has not yet been implemented by the company:

Who are the customers your firm has? To answer this question, we carried out a simple descriptive analysis, which allows to have a general idea of the customer that frequents the retailer. Due to its interactivity, it allows to explore who makes up certain segments that compose the customer base. All variables presented were provided by the company, therefore it is not necessary to carry out any calculations at this stage.

How do these customers differ in terms of their value to the firm? One metric to answer this question is "CLV" which estimates the present value of the future revenues less the costs of initializing, maintaining, and developing the customer relationship [18]. This metric offers a more comprehensive perspective than mere revenue from a customer, as it encompasses costs such as marketing expenses, crucial for maintaining customer relationships. Thus, it provides a more accurate representation than revenue alone. In this instance, a simplified version of the Kumar and Venkatsen [19] equation (Eq. 1), one of the most commonly used for CLV calculation, was chosen.

$$\mathrm{CLV_{it}} = \sum_{t=1}^{T_i} GC_{it} - \sum_{t=1}^{T_i} \sum_{m} MC_{i,m,t} \tag{1}$$

where: $\mathrm{GC_{i,t}}$ = gross contribution from customer i in purchase occasion t; $\mathrm{MC_{i,m,l}}$ = marketing cost for customer i in communication channel m in time period l; $\mathrm{T_i}$ = number of purchases made by customer i

Theoretically, CLV should span the entire customer lifespan, yet predicting that far into the future is impractical [20]. Hence, Baesens and Caigny [20] recommend adopting a shorter time horizon. Given the available data, an annual forecast is conducted, necessitating annual updates. Since the dataset covers two years, it was divided in half. To assess each customer's value, the formula was applied separately for x-1 and x. Thus, it is crucial to label this initial calculation accurately in this context as the Customer Value (CV) for a specific year of the customer's life. Nevertheless, for convenience, the term CLV was retained.

How many customers accounted for half of your revenue last year? To understand how many customers accounted for half of the revenue last year, we decided to construct a customer value pyramid. Customer segmentation into value pyramids, is a technique that classifies customers based on their value to the company [21]. This approach aids in

understanding and identifying groups of customers with similar characteristics, thereby guiding future marketing strategies. In this case, the value of each customer was calculated using the aforementioned CLV formula. Subsequently, percentiles were computed for each year relative to CLV, assigning each customer a score where higher scores correspond to higher values. Consequently, the following segments were created: 100–99 percentile (Top), 99–95 percentile (Big), 95–80 percentile (Medium), and up to 80 percentile (Small).

In this analysis, we focused solely on CLV, as this measure provides a more comprehensive view of profitability when compared to revenue alone. Alongside this pyramid, we established a KPI to understand the contribution of each segment of the pyramid in terms of cumulative CLV value. Specifically, we compared the cumulative value of all customers against the value contributed by the top 20% of customers.

Note that it was opted to use the CLV, because while revenue focuses solely on income generated within a specific period, CLV accounts for the costs associated with acquiring and retaining customers. By subtracting marketing expenses from annual revenue, CLV provides a measure that reflects not only the immediate financial gains but also the investment required to maintain customer relationships. In essence, CLV offers a more nuanced understanding of the financial implications of customer interactions. It highlights the profitability of customers by considering both revenue and associated costs, thus serving as a better indicator of overall business performance and sustainability. Thus, this analysis helps prioritize resources and tailor strategies to retain and maximize revenue from high-value customers.

How many customers who bought your products last year can be expected to buy from you this year? To answer this question a metric called "Customer Trasition", helps the company to identify if a customer is more propense to loose value or not. This involves predictive modeling techniques, such as machine learning algorithms, to forecast customer repurchase probabilities based on historical data.

In order to forecast the number of customers expected to make purchases this year based on their previous year's buying behavior; decision trees were utilized. The "Transition State" indicator was employed to determine the anticipated purchasing behavior of individuals. Those categorized as "Decrease" are projected to lose value (i.e., transition to a lower segment) of the value pyramid, implying a decrease in purchases compared to the previous year. Conversely, individuals classified as "Not Decrease" are expected to either maintain or ascend in segment, thus retaining or increasing their purchasing value for the upcoming year (these are the individuals expected to make purchases in the forecasted year).

This approach extends beyond mere prediction of how many customers are expected to purchase, by integrating the segments of the value pyramid to determine if the customer will descend to a lower segment. Consequently, instead of dichotomizing between purchasers and non-purchasers, all individuals potentially inclined to buy and spend less are considered. This strategy holds particular significance as it empowers retailers to intervene proactively before customers cease purchasing altogether.

6 Results

In this section, the results for each of the previously presented questions are presented.

6.1 Who are the Customers Your Firm has?

In this case, the typical customer is from Lisbon (46,57%), female (60,34%), active adult (48,73%), between 36 and 65 years old (60,46%), that prioritizes the price of the product (47,96%) (Fig. 2).

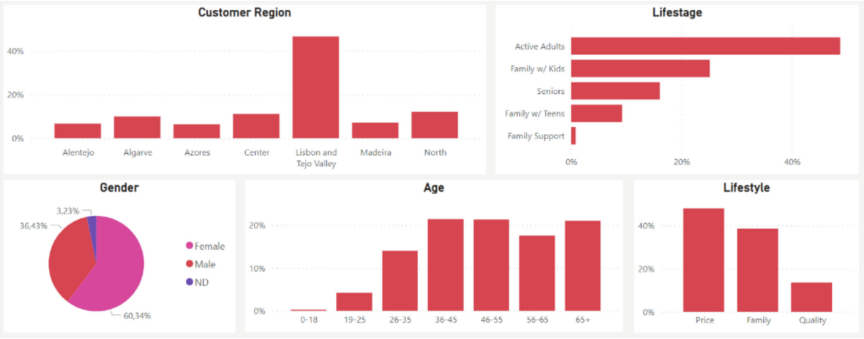


Fig. 2. Customer Descriptives

6.2 How do These Customers Differ in Terms of Their Value to the Firm?

Contrary to conventional belief [2], when describing how customers vary by CLV, a commonly invoked assumption is that of a normal distribution. However, this is a myth and a common mistake. In fact, when it comes to CLV distribution the lower-value customers make up the largest proportion (Fig. 3). This vision lines up with the "80:20 rule", that is the 80% of your customers bring only 20% of the value [2]. In this case, 80% of the customers (n = 58865) bring only 40% of the total value.

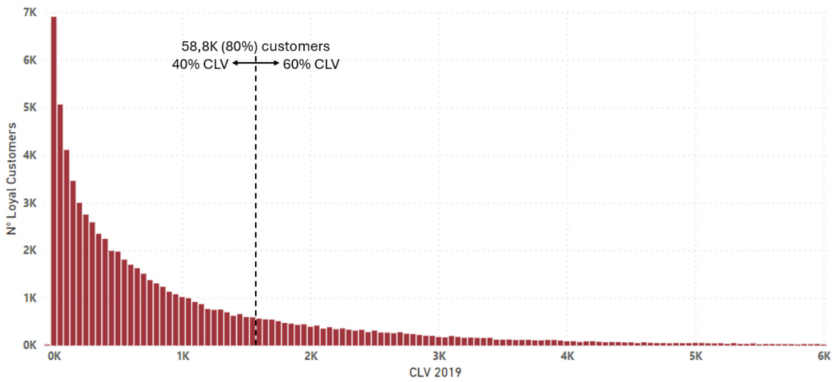


Fig. 3. CLV Distribution

6.3 How Many Customers Accounted for Half of Your Revenue Last year?

The total customers CLV is 74.13 million m.u. (monetary units); however, if we look only to the top 20% of customers, they represent 44.3 million m.u., which is more than half (Figs. 4 and 5).

This confirms the principle that the top 20% of customers are responsible for most revenues/profits.

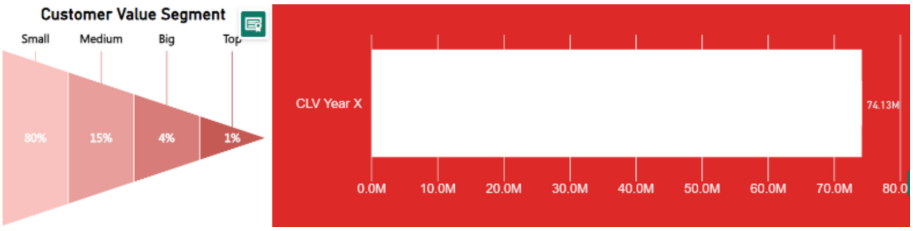


Fig. 4. Total CLV

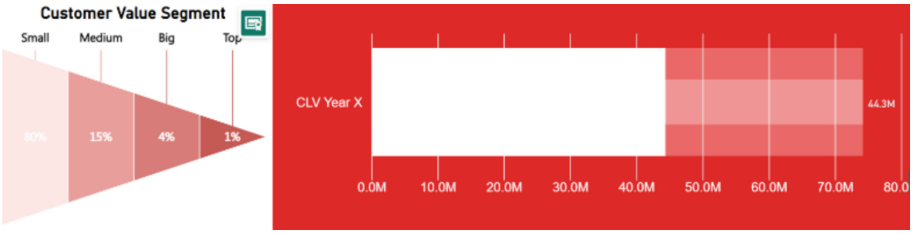
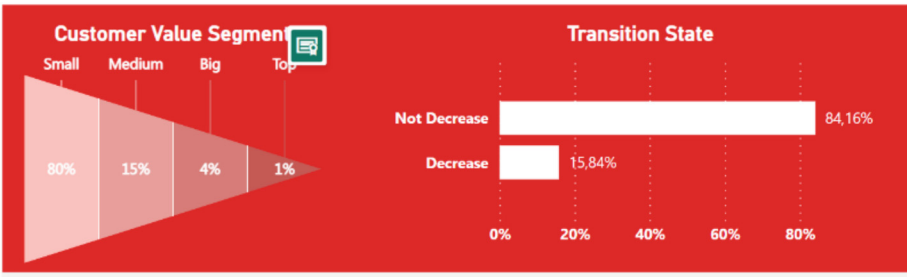


Fig. 5. Top 20% CLV

6.4 How Many Customers Who Bought Your Products Last year can be Expected to Buy from You This year?

The model predicts that approximately 15% of the total customers will decrease to a lower segment in the value pyramid, this means that the retailer can count that approximately 85% will buy in the forecasted year maintaining at least their current interspace value associate to their segment (Fig. 6).

It was also included the option to the retailer select a specific segment, this allows the company to focus on the top customers if they intend to. From this point the firm can extract the customer information and dive into a deeper analysis to try to recover the 15% expected to lose value.



Customer_Number	Age_Dsc	Lifestage_Dsc	Lifestyle_Dsc	Customer_Region_Dsc	Gender_Dsc	Decrease_Dsc
17816	56-65	Active Adults	Family	North	Female	Not Decrease
18495	46-55	Active Adults	Quality	Lisbon and Tejo Valley	Female	Not Decrease
18631	46-55	Active Adults	Quality	Lisbon and Tejo Valley	Female	Decrease
18667	46-55	Active Adults	Family	Lisbon and Tejo Valley	Male	Decrease
18680	65+	Seniors	Family	North	Male	Not Decrease

Fig. 6. Transition Prediction

7 Conclusions

The analysis and report of customer bases, while somewhat uncommon, are acknowledged as fundamental practices by some of the world's largest and most prestigious strategic consulting firms [3, 17]. As of today, we are witnessing an increasing number of companies incorporating this type of information into their audit reports [4]. However, to achieve this, it is essential to understand how to actively address the most elementary and pervasive guidelines.

To accomplish this, in addition to outlining the methodology and calculation methods, it was chosen to develop a dashboard aimed at encompassing the various metrics and indicators involved. For the construction and implementation of this dashboard, a real-world case study was employed, featuring a company that had not previously employed such analyses. This practical approach allows for a tangible demonstration of how to apply these concepts in a real business context, facilitating better understanding and implementation within organizations.

7.1 Contributions

The contributions of this study are twofold: academic and practical. From an academic standpoint, it presents, for the first time, a methodological framework for addressing the fundamental questions that any company's customer base audit report should answer. Additionally, it elucidates the various metrics and indicators involved, along with the possible visualizations for presenting these results.

On a practical level, this study stands out for its inclusion of a tactical dashboard for customer base audit reporting in a company that had not previously conducted this type of analysis. This implementation underscores the tangible application of the research findings, providing a concrete tool for enhancing strategic decision-making and performance evaluation within the organization.

7.2 Limitations and Future Investigations

The limitations found in this study are the time limitations, given the focus on a certain period of time, as well as the focus on a single retail chain.

In this study, as previously mentioned, the analysis was built on a database referring to the transactions of customers between two years, which is a time limitation. The fact that this study is focused on the customers of a single retailer is also a limitation since these customers could not represent reality across all the retailers but rather peculiar characteristics of the retailer in question. As it is located in Portugal, it finds itself in a macroeconomic context of low inflation, whereas for other countries, the same may not be true.

For the future, it would be very interesting to: (1) Use more data (more years) from different retail companies; (2) Build a customer management strategy based on the dashboard developed, evaluating the impact over time; (3) Explore other customer-base audit questions through KPIs and visualizations.

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Patterns Beyond Words: Understanding Emotional Undertone on Knowledge Graphs

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Abstract. This study introduces a novel approach to generating temporal knowledge graphs annotated with sentiment analysis. Leveraging natural language processing and graph theory, we analyze how sentiment toward various topics evolves over time. Through a robust methodology, we identify key terms and their interrelationships. Our analysis unveils the progression of major themes, the terms with the highest sentiment growth, and the relationship between sentiment and academic impact. This work provides a comprehensive view of the emotional undertones in academic literature and offers insights into emerging trends and their potential implications.

Keywords: Temporal Knowledge Graphs · NLP · Sentiment-annotated Knowledge Graphs · Emotion Undertone · Sentiment Analysis · Network Science · ACII

1 Introduction

Human communication is a complex process that involves much more than just the literal content of the message. Emotional undertones, which convey deeper meaning, are an important aspect of communication, and understanding them is a challenging task that has recently received increasing attention. One area where this understanding is unseen is in the analysis of knowledge graphs, which are structured representations of knowledge used for various tasks such as information retrieval and question answering. Furthermore, understanding emotional undertones in knowledge graphs can lead to a more comprehensive understanding of human behavior and decision-making, with implications on diverse fields such as psychology, sociology, and political science. Finally, developing AI systems that account for emotional impact can lead to more ethical and responsible AI.

Understanding emotional undertones in human communication is a challenging task that has received increasing attention due to its importance in conveying deeper meaning [1]. While there has been substantial research in the areas of sentiment analysis, human-robot interaction, and emotion recognition, there remains a noticeable gap in the literature concerning the temporal evolution of emotional undertones in structured data such as knowledge graphs. For instance, the study by Cariola [2] delves into language

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use and emotional expression in mother-adolescent interactions but does not consider the temporal dimension of sentiment. Similarly, the work by DaSilva [3] investigates how the physical design of robots affects human-robot interactions, but it doesn't extend its focus to the emotional undertones embedded in textual or knowledge graph data. Moreover, previous research [4–6] employs neural networks for emotion recognition in dialogue systems but does not consider emotional undertones in a more structured context like knowledge graphs. Therefore, our study aims to fill this research gap by proposing a methodology for generating a temporal knowledge graph with sentiment analysis' annotations. The primary objective is to understand how emotional undertones associated with specific topics evolve over time. This not only extends the existing literature but also holds broad impact on various fields, including psychology, human-computer interaction, and product design.

The implications of this methodology are multifold. By capturing the dynamic emotional undertones in text with a topological view, we can gain deeper insights into the present emotion at knowledge creation, and thereby further understanding its impact on emerging research trends. The sentiment-annotated knowledge graph also paves the way for more empathetic human-computer interactions and can guide the design process to align products more closely with user emotions.

2 Theoretical Background

Emotional undertones are an important aspect of human communication, as they convey meaning beyond the literal content of the message. Understanding emotional undertones in text is a challenging task that has received increasing attention in recent years [1–13]. One application of this task is in the analysis of knowledge graphs, which are structured representations of knowledge that can be used for various tasks, such as information retrieval and question answering.

One approach to understanding emotional undertones in knowledge graphs is through the use of sentiment analysis techniques. Sentiment analysis primarily involves the identification, classification, and quantification of emotions expressed in text, such as positive, negative, or neutral. Several studies have explored the use of sentiment analysis in the context of knowledge graphs, such as the work by He et al. [7] who proposed a multi-task learning framework to jointly predict entity types and sentiment labels for entities through knowledge graphs. Other studies have focused on incorporating sentiment analysis into question answering systems that use knowledge graphs, such as the work by Nguyen et al. [8] who proposed an approach to extract emotion-cause to generate responses to user queries. Yet, the task of sentiment-aware question answering using knowledge graphs remains unexplored.

Another approach to understanding emotional undertones in knowledge graphs is through the use of emotion ontology. Emotion ontology is a structured representation of emotions and their relationships, which can be used to annotate text and knowledge graphs with emotional information. The work by Grassi et al. [9] proposed an emotion ontology for natural language processing tasks, which includes a set of emotion categories and relationships between them, which was then further explored in more recent studies [10, 11].

In addition to sentiment analysis and emotion ontology, other studies have explored the use of machine learning techniques aided by knowledge graphs for understanding emotional undertones. For example, the work by Nie et al. [12] proposed an approach to acquire relevant background from knowledge graphs for guiding emotional classification tasks. Other studies have explored the use of graph-based approaches for sentiment analysis and emotion detection in knowledge graphs, such as the work by Yu et al. [13] who proposed a multimodal graph-based approach for emotion detection based on facial expressions.

Understanding emotional undertones in knowledge graphs is an important task that has received increasing attention in recent years. Several approaches have been proposed, including sentiment analysis, emotion ontology, and machine learning techniques. These approaches have the potential to enhance the usability and effectiveness of knowledge graphs for various tasks, such as information retrieval, question answering, and decision making.

There are various applications and implications of understanding emotional undertone on knowledge graphs. One application is in the field of sentiment analysis, where knowledge graphs can be used to model and analyze the sentiment of different entities and events [7, 8]. By incorporating emotional undertone into sentiment analysis, knowledge graphs can provide a more nuanced understanding of the emotional context of different entities and events, which can be useful in fields such as marketing, social media analysis, and customer service [7, 13].

Another application is in the development of intelligent systems that can recognize and respond to emotions. For example, knowledge graphs can be used to model the emotional responses of users in human-computer interaction, allowing for more personalized and empathetic interactions with technology [13]. Additionally, emotional undertone on knowledge graphs can be used to improve the design and user experience of products and services by considering emotional factors that influence user behavior and decision-making [14].

The implications of understanding emotional undertone on knowledge graphs extend beyond specific applications. A deeper understanding of the emotional context of different entities and events can lead to a more comprehensive understanding of human behavior and decision-making, which has implications for fields such as psychology, sociology, and political science [15, 16]. Moreover, recognizing and accounting for emotional undertone on knowledge graphs can guide the development of more ethical and responsible AI systems that consider the emotional impact of their decisions and actions on humans [17].

3 Methodology

Our methodology employs a synergistic combination of natural language processing techniques, sentiment analysis methods, and graph database technology to generate a temporal knowledge graph annotated with sentiment scores. The overarching goal is to facilitate the understanding of emotional undertones in textual data over time. Below, we outline each step of the methodology in detail, complete with mathematical formulations to provide a context for the framework in Fig. 1, inspired by previous work [24–27].

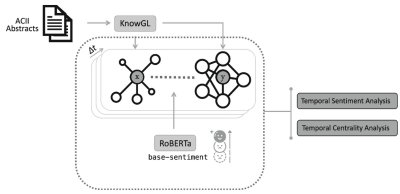

Fig. 1. High-level scheme of the proposed framework.

3.1 Data Collection

The first stage involves collecting a diverse corpus of text data, denoted by $D = \{d_1,d_2,...,d_n\}$, from various platforms such as social media, news articles, and online forums. Here, n represents the total number of documents collected, with each document containing textual data relevant to the subjects of interest. The corpora used for this research is the set of abstracts, titles and citations from the ACII conference from 2007 to 2022. Yet, given computational constraints, for certain specific analysis we uniformly sampled 350 of the most recent papers.

3.2 Text Preprocessing

The raw text in each document $d_i \in D$ undergoes state-of-the-art natural language preprocessing to generate a set of tokens $T_i = \{t_{i1},t_{i2},...,t_{im}\}$. This set contains m tokens extracted from document d_i. Preprocessing techniques such as text cleaning, normalization, and stop-word removal are employed, utilizing tools like NLTK [18] and spaCy [19]. For classifying semantic information and interconnection of entities, we used the KnowGL [20] model based on BERT and trained on datasets based on wiki data triplets and abstracts, which is suggested for detecting specific expressions from the literature.

3.3 Sentiment Analysis

Each token in T_i is mapped to a sentiment score through a function S: $T_i \rightarrow [0,1]$. The aggregate sentiment score for T_i is computed as $S(T_i) = \sum_{t \in T_i} S(t)$.

Various approaches to sentiment analysis, including rule-based, machine learning, and lexicon-based methods, could be used based on the task and data characteristics [21–23]. Yet, given the fast development of current machine learning models to perform such tasks, we used a model based on RoBERTa fine-tuned for sentiment analysis [1]. This model outputs a 3-dimensional vector corresponding to the positive, neutral and negative emotional tones. Each vertex $v \in V$ is annotated with a sentiment score $S(v)$ calculated based on a sentence level classification.

3.4 Knowledge Graph Generation and Analysis

A directed graph $G = (V,E)$ is generated to represent the relationships between the tokens. The set V contains unique tokens across all T_i, and E consists of edges representing co-occurrences of tokens, $E \subseteq V \times V$. Temporal trends in sentiment scores are analyzed

along with network science metrics to understand specific dimensions of the emotional tones' evolution. For each vertex v, the sentiment score at time t is defined as $T(v,t) = \sum_{d_i \in D_t, v \in T_i} S(T_i)$, where D_t is the subset of documents from D belonging to the time period t.

4 Results and Discussion

In this section, we present the findings of our study, illustrated by a series of figures that each shed light on different aspects of the research on the ACII 2007–2023 corpora of published scientific articles on Affective Computing.

4.1 Thematic Analysis

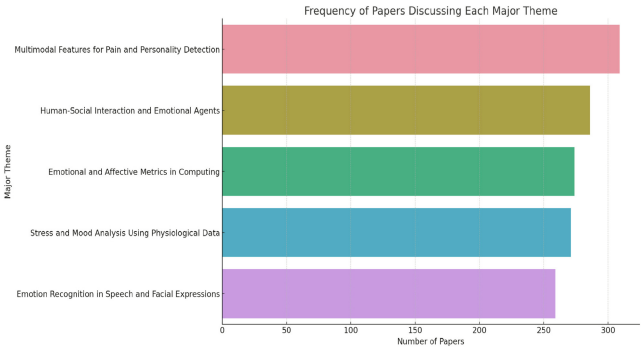

Fig. 2. Frequency of papers discussing each major theme.

Figure 2 displays the frequency with which each major theme is discussed across the literature. This Fig. Helps to identify the most dominant themes and can be used to gauge the overall interest in specific research areas. It shows that the distribution of themes is fairly balanced, and Multimodal features are on the lead.

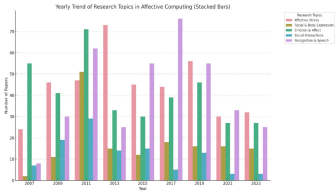

Fig. 3. Progression of major themes over time.

Figure 3 shows the progression of major themes over time, providing insights into how academic focus has shifted. This can aid in understanding the evolving landscape

of the field. We see an overall increase until 2018 and then a slight decrease afterwards, denoting an increasing research prevalence on minor and emerging themes. The focus has also slightly shifted along time.

4.2 Knowledge Graph Analysis

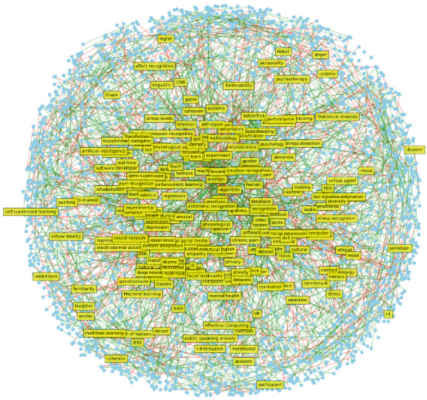

Fig. 4. Knowledge graph representation.

Figure 4 presents the knowledge graph constructed from the analyzed documents. The graph serves as a structural representation of the relationships among various themes, topics, and terms discussed in the literature.

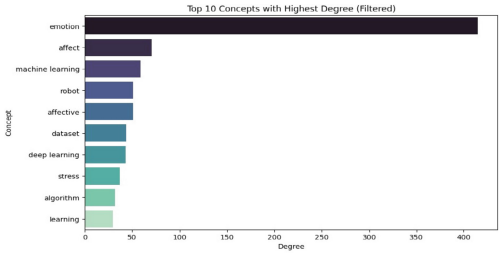

Fig. 5. Highest degree terms in the knowledge graph.

Figure 5 highlights the terms with the highest degree in the knowledge graph. These terms can be considered as central nodes that connect various other nodes, making them influential in the context of the research landscape. Emotion related terms are on the lead, followed by machine learning, robot, dataset and deep learning.

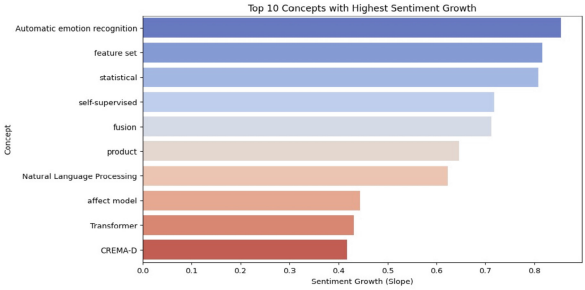

Fig. 6. Highest sentiment growth terms.

4.3 Sentiment Analysis

Figure 6 shows the terms that have seen the most significant growth in sentiment over time. This can help to identify emerging positive or negative attitudes toward specific topics in the field. This seems to be the case of *Automatic emotion recognition.* Yet, this growth may take several forms. Similarly, *fusion, HCI, NLP, affect model, experimentation*, and *Transformer* form the model family.

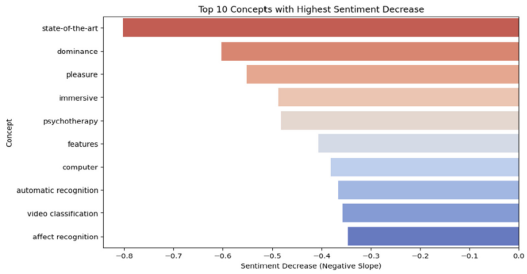

Fig. 7. Bar plot showing the top 10 concepts with the highest sentiment decrease over time.

Figure 7 reveals the top 10 concepts that have shown the most significant decrease in sentiment over time. Understanding the negative trends in sentiment for these key concepts could have multiple implications. It may signal shifts in public or scholarly perception and could point to areas where intervention or further investigation is needed. This can be especially useful in fields like public policy, marketing, and social sciences to understand changing attitudes and to develop informed strategies. *State-of-the-art* is an expected term since it is increasingly less common to explicitly mention the gap of the state of the art in the abstract.

Figure 8 illustrates how the sentiment associated with specific terms has evolved over time. This temporal view can provide valuable insights into how perceptions are changing. For instance, we see that expression Facial expression recognition shows a steep decline. However, depression and gender seem to be growing in sentiment.

Figure 9 presents the average sentiment trend across all terms and themes, providing a general sense that the communication in the field is stable along time.

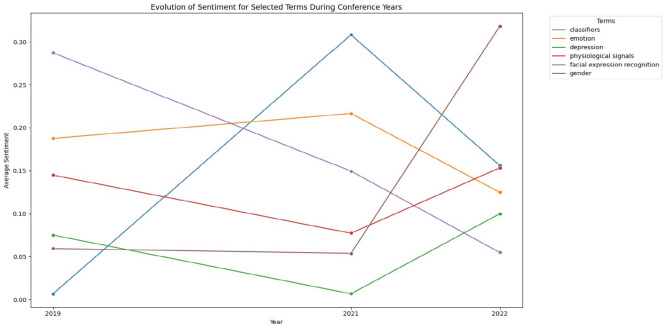

Fig. 8. Progression of term sentiment over time.

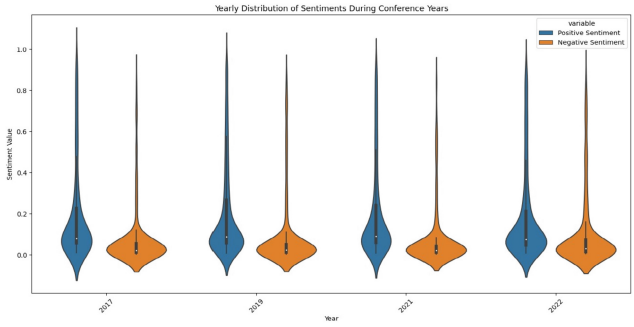

Fig. 9. Average sentiment trend.

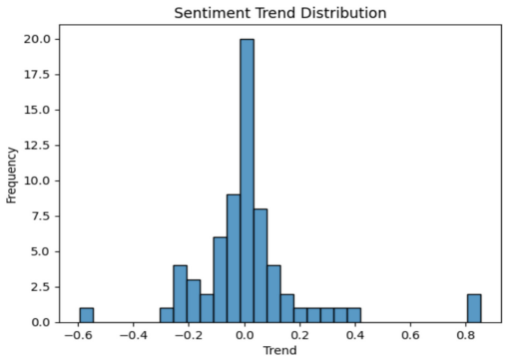

Fig. 10. Distribution of sentiment trend (growth).

Figure 10 shows the distribution of sentiment growth rates for all terms. This can help to identify outliers and terms that require further investigation. Interestingly, we see a distribution close to normal showing a tendency for maintaining the same level of sentiment when describing most terms. We also see the tendency for loosing or increasing

sentiment trend is similar. This is probably because researchers are shifting the focus from one theme to another.

4.4 Statistical Relations

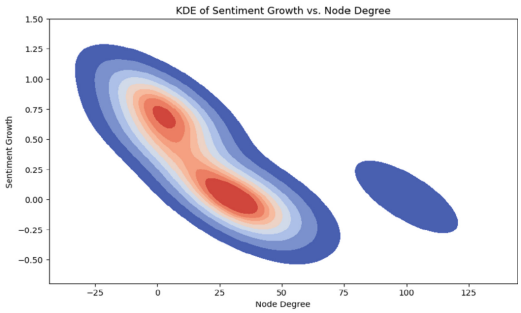

Fig. 11. KDE relating positive sentiment growth with degree.

Figure 11 presents a Kernel Density Estimate (KDE) plot that relates positive sentiment growth with node degree in the knowledge graph. This statistical view can help to identify whether more central terms are associated with more positive sentiment growth. Yet we see a fairly consistent view that shows us that the node degree is usually inversely proportional to the growth in sentiment. This may be because it might be exciting for researchers to see terms that are not too well connected as an opportunity.

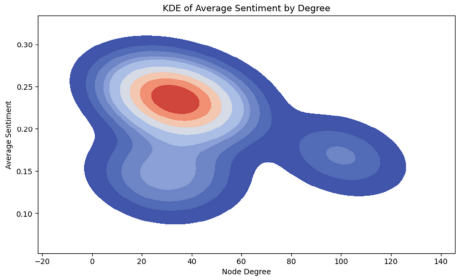

Fig. 12. KDE relating average sentiment with degree.

Figure 12 presents a KDE plot that relates average sentiment with node degree. This aids in understanding how the importance of a term in the graph correlates with its average sentiment. This graph complements the previous one by showing that the average sentiment of a term over the years is also related to less well-connected nodes.

Figure 13 explores the relationship between sentiment and the number of citations. This could imply how sentiment may influence the academic impact of certain terms or topics. We see that less negative sentiment in topics is related with higher citation levels, but this relationship is not that trivial with neutral and positive sentiment.

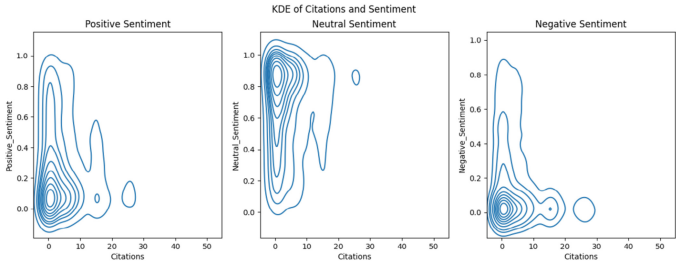

Fig. 13. Relationship between sentiment and citations.

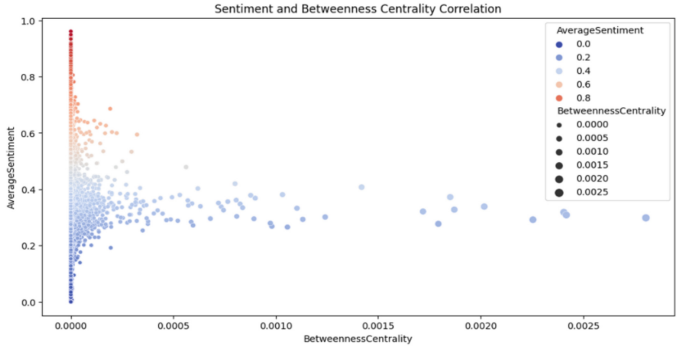

Fig. 14. Relationship between average sentiment and betweenness centrality.

Figure 14 illustrates the relationship between average sentiment and betweenness centrality, offering insights into how nodes that connect other nodes are perceived sentimentally. This shows us that the bridges between other topics range from fairly neutral to weak negative sentiment.

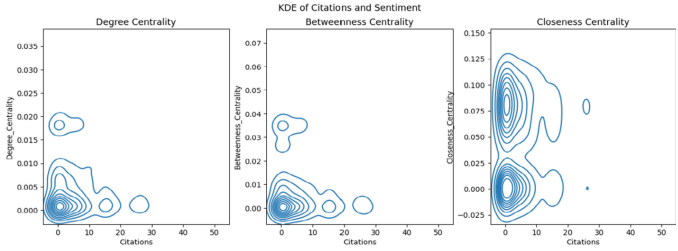

Fig. 15. Relationship between centrality and citations.

Figure 15 shows the relationship between node centrality measures and the number of citations, implying how structural importance in the knowledge graph might relate to academic impact. This shows us that higher Closeness centrality has a slightly higher tendency to be related to high citations. And low centrality terms have a higher probability

of being cited. This is a counter intuitive notion since we would expect that the high centrality represented well established terms.

5 Concluding Remarks

This study has presented a comprehensive approach for generating temporal knowledge graphs with sentiment annotations. Through a rigorous methodology encompassing data collection, text preprocessing, sentiment analysis, knowledge graph generation, and temporal analysis, we have achieved several key findings. Firstly, the frequency of papers discussing each major theme provides an overview of focus areas in the research community. Secondly, the progression of these themes over time reveals evolving research interests. Sentiment analysis further adds a layer of depth, allowing us to understand the emotional undertones associated with specific terms and themes. The empirical results collected from a specific field of knowledge revealed that showed that terms with higher centrality measures do not tend to have higher academic impact, as measured by citations. The Kernel Density Estimate (KDE) plots also shed light on the complex interplay between sentiment, academic impact, and centrality in the knowledge graph. These findings can be invaluable for understanding customer feelings, improving computer interactions, and designing better products. There are, however, limitations to this study. The sentiment analysis, while robust, is still subject to the nuances of human emotion, which is often context dependent. Future work could involve more advanced sentiment analysis techniques and the incorporation of additional data sources. This study serves as an effort in understanding the temporal and emotional dimensions of academic literature. It opens the door for further research into the dynamics of sentiment in academic discourse and its broader implications.

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Socio-Economic Consequences of Generative AI: A Review of Methodological Approaches

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Abstract. The widespread adoption of generative artificial intelligence (AI) has fundamentally transformed technological landscapes and societal structures in recent years. Our objective is to identify the primary methodologies that may be used to help predict the economic and social impacts of generative AI adoption. Through a comprehensive literature review, we uncover a range of methodologies poised to assess the multifaceted impacts of this technological revolution. We explore Agent-Based Simulation (ABS), Econometric Models, Input-Output Analysis, Reinforcement Learning (RL) for Decision-Making Agents, Surveys and Interviews, Scenario Analysis, Policy Analysis, and the Delphi Method. Our findings have allowed us to identify these approaches' main strengths and weaknesses and their adequacy in coping with uncertainty, robustness, and resource requirements.

Keywords: Generative AI · AI adoption · methods · prediction · methodology

1 Introduction

In recent years, generative artificial intelligence (AI) usage has revolutionized technological landscapes and profoundly reshaped the societal structure. This transformative force, marked by its ability to generate novel content, ideas, and solutions autonomously, has sparked unprecedented levels of innovation across various sectors [14, 22, 41, 51, 53]. However, alongside its potential for progress, generative AI also brings forth a plethora of uncertainties and complexities, emphasizing the urgent need for structured evaluation methodologies.

As society struggles with the implications of this technological revolution, the imperative to develop robust and scalable analytical frameworks becomes increasingly evident [17, 22]. The unpredictable yet extensive impacts of generative AI underscore the

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necessity of comprehensively understanding its implications. From its effects on workforce dynamics to its influence on socio-economic structures and cultural norms, the multifaceted nature of AI innovation demands a nuanced evaluation approach.

In the research reported here, we embark on a comprehensive exploration motivated by the tension between the unforeseeable shifts brought about by generative AI and the necessity for structured evaluation methodologies. This exploration is driven by the acknowledgment that while the potential benefits of AI innovation are vast, so are the associated challenges and risks. Therefore, our effort aims to solve the complexities inherent in this technological revolution and provide insights to inform strategic decision-making and policy formulation in an era of unprecedented change.

Our investigation examines various methodologies, ranging from traditional econometric models to cutting-edge reinforcement learning techniques tailored for decision-making agents. Agent-Based Simulation (ABS), Input-Output Analysis, Surveys and Interviews, Scenario Analysis, Policy Analysis, and the Delphi Method all feature prominently, each offering unique insights into the intricate dynamics entwined with the proliferation of generative AI. They are synthesizing insights gleaned from these methodologies. Recognizing the nuanced interplay between technological advancement and its societal ramifications, we argue that such an integrative approach is essential for comprehensively understanding the transformative effects of generative AI.

Moreover, by shedding light on the multifaceted consequences of AI innovation, our research aims to facilitate informed decision-making and policy formulation in the face of unprecedented technological change. Through this integrative lens, we aspire to contribute to a deeper comprehension of the societal implications of AI innovation, empowering stakeholders to navigate the complexities of an increasingly AI-driven world with foresight and discernment.

2 Literature Review

From the literature [1–19, 48], the following methodologies are commonly used to analyze the impact of adopting new technology. The choice of method depends on the specific research questions, available data, and the complexity of the economic system under consideration [48]. We may identify as possible methods the Fig. 1.

Agent-based modeling (ABM) consists of modeling individual entities (agents) and their interactions within a system [1]. Each agent follows predefined rules or behaviors, and the simulation explores the emergent properties resulting from these interactions. ABM is used to understand complex systems and study how local interactions lead to global patterns [2, 50]. ABM allows for modeling complex behavior patterns and provides valuable information about the dynamics of real-world systems [3]. It can incorporate learning techniques such as neural networks and evolutionary algorithms to enable realistic learning and adaptation [9]. ABM has broad applications in various fields, including ecology, evolution, economics, and social sciences [10].

Econometric models use statistical methods to analyze relationships between economic variables [4]. These models are based on historical data and aim to estimate and quantify the impact of different factors on economic outcomes [7]. Econometric models are commonly used in forecasting and policy analysis [11, 49]. Econometric models provide a robust framework for analyzing the impact of generative AI on economics across

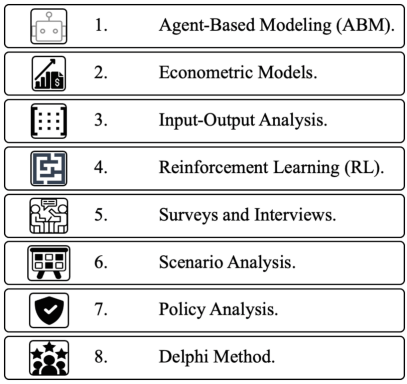

Fig. 1. Methods

multiple dimensions. These models enable researchers to examine AI adoption patterns, labor market dynamics, productivity growth, market competition, policy implications, and long-term economic outlook. By leveraging historical data and statistical methods, econometricians can quantify the effects of generative AI on variables such as employment levels, wages, innovation, market dynamics, and economic welfare. Econometric analyses shed light on how AI-driven innovations influence productivity, consumer behavior, firm profitability, and regulatory responses. Through rigorous modeling and simulation, policymakers can anticipate the economic consequences of AI adoption and design policies that foster innovation, mitigate risks, and ensure equitable outcomes in AI-driven economies. In essence, econometric models serve as invaluable tools for understanding and navigating the complex interactions between generative AI and economics, providing insights that inform decision-making and shape the future trajectory of economic development.

Input-output analysis examines the interdependencies between different economic sectors [5, 20]. It quantifies how changes in one sector impact others by analyzing the flows of goods and services [6]. Input-output models help understand the ripple effects of economic changes [6]. Input-output analysis, which examines the interdependencies among economic sectors and quantifies the flow of goods and services, is a valuable tool for predicting the impact of generative AI in economics. By understanding how changes in one sector affect others, input-output models can anticipate the ripple effects of AI-generated goods and services across various industries. For instance, as generative AI technologies become prevalent in creative content production, such as art and music, input-output analysis can forecast the downstream effects on related sectors like entertainment and advertising. Additionally, it can assess the potential labor displacement resulting from increased automation facilitated by generative AI. By simulating different scenarios and analyzing economic activity flows, stakeholders can better anticipate and manage the consequences of AI-driven innovation, making input-output analysis essential for policymakers, businesses, and researchers navigating the complexities of the evolving economic landscape.

Reinforcement learning (RL) is a machine learning paradigm where an agent learns to make decisions by interacting with an environment [13]. In RL for decision-making agents, the focus is on modeling the decision-making processes of individual entities. Agents learn optimal strategies through trial-and-error interactions [13]. RL involves the exploration of solution spaces within a simulated environment to optimize decision-making [14]. RL can be combined with agent-based models (ABMs) to address the self-organizing dynamics of social phenomena and explore the space of possibilities that emerge from considering different types of incentives [15]. Reinforcement learning (RL) presents a potent methodology for forecasting the implications of generative artificial intelligence (AI) within economics. By employing RL, researchers can simulate the decision-making processes of economic agents interacting with generative AI systems. RL algorithms allow for iterative learning through trial-and-error interactions, enabling agents to optimize their strategies based on feedback. Additionally, RL facilitates the exploration of solution spaces within simulated environments, aiding in identifying optimal decision-making strategies amidst complex economic scenarios influenced by generative AI. Integration with agent-based models (ABMs) further enhances understanding by capturing heterogeneous agents' dynamic interactions and emergent behaviors. RL techniques can also inform incentive design and policy formulation, optimizing reward structures and decision mechanisms to guide economic agents' behavior in AI-driven environments. Overall, RL serves as a valuable tool for anticipating and shaping the economic impacts of generative AI, providing insights crucial for designing robust and adaptive economic policies.

Surveys and interviews involve collecting data through structured questionnaires [52, 56] or direct interviews with individuals. In the context of economic analysis, surveys and interviews can gather opinions, preferences, and insights from key stakeholders, such as businesses, policymakers, or consumers [12]. Surveys and interviews serve as invaluable tools in predicting the impact of generative AI in economics by capturing diverse stakeholders' perspectives and insights. These methods facilitate understanding current perceptions and awareness of generative AI technologies, identifying potential use cases, and assessing associated opportunities and challenges. Through gathering expert opinions and stakeholder feedback, surveys and interviews enable forecasting economic impacts, including productivity gains, changes in employment dynamics, and implications for market structures and income distribution. Moreover, the data collected can inform the development of policies and strategic initiatives to maximize benefits and minimize risks associated with integrating generative AI into economic systems, ultimately contributing to informed decision-making and fostering inclusive economic growth.

Scenario analysis involves creating and exploring multiple future scenarios based on different assumptions or conditions. It helps decision-makers understand potential outcomes under various circumstances and develop strategies to navigate uncertainty [16]. Scenario analysis is a strategic forecasting technique that can be employed to anticipate the impact of generative AI in economics. By identifying key drivers such as technological advancements, regulatory frameworks, and societal attitudes, scenario analysis involves creating a variety of plausible future scenarios. These scenarios explore different combinations of factors to understand their potential implications on economic aspects

like productivity, employment, and market dynamics. Through quantitative modeling and qualitative assessments, decision-makers can evaluate the risks and opportunities associated with each scenario, informing strategic planning and policy development. Scenario analysis is an iterative process, allowing stakeholders to continuously refine their understanding of the potential impacts of generative AI and adapt their strategies accordingly. Ultimately, scenario analysis provides a structured approach to navigating uncertainty and making informed decisions in the face of emerging technologies like generative AI.

Policy analysis evaluates the effectiveness of policies and interventions in achieving specific goals. In the context of economic impact analysis, policy analysis assesses how different regulatory frameworks, incentives, or interventions may influence economic outcomes [17, 54, 55]. Policy analysis offers a valuable framework for predicting the impact of generative AI in economics by systematically evaluating potential outcomes and crafting appropriate responses. It involves identifying how generative AI could influence economic dynamics, including changes in production processes, labor markets, consumer behavior, and market structures. Through scenario planning and cost-benefit analysis, policymakers can anticipate challenges and opportunities associated with adopting generative AI technologies, informing the design of regulatory frameworks and incentive structures. By engaging diverse stakeholders and considering ethical considerations, policymakers can develop evidence-based policies to maximize the benefits of generative AI while mitigating risks, thus ensuring responsible innovation and fostering economic growth in the AI-driven era.

The Delphi Method is a structured, iterative forecasting technique that gathers expert opinions through surveys or questionnaires [18]. Experts anonymously provide feedback on a specific topic, and the process continues until consensus or stability is reached. The method is useful in situations with high uncertainty [19]. The Delphi Method, a structured forecasting technique, can be employed to predict the impact of generative AI in economics by assembling a diverse panel of experts in economics and artificial intelligence. Through a series of iterative surveys, experts anonymously provide feedback on the potential effects of generative AI in various economic domains, such as productivity, labor markets, and decision-making processes. The process involves defining the study scope, designing open-ended questionnaires, aggregating responses, refining questions based on initial analysis, and iteratively repeating surveys until consensus or stability is achieved. By synthesizing expert opinions, the method generates predictions about the impact of generative AI in economics, considering diverse perspectives and uncertainties. These predictions can inform policymakers, researchers, and industry professionals in making informed decisions and preparations for the future.

By employing these methodologies, researchers can gain valuable insights into the economic implications of generative AI and its impact on various sectors of the economy. A preliminary evaluation (in Table 1) may consist of a general identification of each approach's main strengths and weaknesses.

Table 1. Strengths and Weaknesses.

Method	Strengths	Weaknesses	Ref
Agent-Based Modeling (ABM)	Simulates dynamic interac-tions, explores emergent impacts	Data intensive relies on model assumptions, complex	[3, 21]
Economet-ric Models	Predicts economic impacts, leverages historical data	Simplified assumptions, limited to economic aspects, potentially inaccurate	[22]
Input-Output Analysis	Tracks economic flows, pre-dicts production shifts	Limited to economic impacts, ignores social/cultural aspects, data requirement	[20]
Rein-forcement Learning (RL)	Adapts to changing environments, predicts system/human interaction evolution	Extensive training data, limited generalizability, potential biases	[8]
Surveys and Inter-views	Gathers direct opinions, un-derstands human perceptions	Limited representativeness, prone to biases, not good for long-term predictions	[12]
Scenario Analysis	Explores different futures, facilitates strategic planning	Relies on scenario quality, doesn't offer precise predictions	[16]
Policy Analysis	Assesses policy impacts, aids decision-making	Focuses on specific policies, overlooks broader changes, requires comprehensive policy options	[17]

3 Methology

These methods offer diverse approaches to studying and understanding the economic impact of various factors, such as the introduction of new technologies like generative AI. In order to evaluate those approaches, the following criteria must be used: uncertainty, robustness, scalability, and resource requirements. The methodology's alignment with the study's objectives is supported by Johnson and Onwuegbuzie [24], who advocate for mixed methods research as a comprehensive approach to address diverse research questions. Tashakkori and Teddlie further underscore the importance of integrating qualitative and quantitative methods to enhance research depth and breadth [25]. Creswell emphasizes the necessity of selecting a methodology that resonates with the research aims and questions, ensuring ethical and academic integrity [26]. Uncertainty acknowledges the adaptability of methods to unpredictable conditions, while robustness evaluates consistency across diverse scenarios, which is crucial for ensuring reliability [24]. Scalability addresses the applicability of methods to extensive datasets, a key factor in managing

computational efficiency [25]. Lastly, resource requirements consider the practicality of method implementation, balancing the need for detailed analysis with the constraints of available resources [26]. This multifaceted evaluation ensures a thorough and grounded selection of methodologies, aligning with both the research objectives and the practical realities of implementation [48]. These references collectively justify the chosen methodological framework, highlighting its capability to yield nuanced insights within a rigorous ethical and theoretical context.

Uncertainty indicates a method's ability to acknowledge and handle high levels of uncertainty or unpredictability in the analysis.

1. High: Methods with high uncertainty often involve subjective judgments, assumptions, or scenarios that may vary widely.
2. Moderate: Reflects a balanced consideration of uncertainty, acknowledging potential variations in outcomes or predictions. The method incorporates a degree of flexibility in response to changing conditions or unknowns.
3. Low: Suggests a method that tends to produce more deterministic or predictable outcomes, with limited consideration for uncertain factors. The approach may rely heavily on historical data or well-defined rules.

Robustness indicates the resilience of a method to variations or changes in input parameters, assumptions, or conditions.

1. High: A robust method is less sensitive to uncertainties and can produce consistent results across different scenarios.
2. Moderate: Reflects a method's ability to handle variations to some extent. It may be robust under certain conditions but could exhibit sensitivity in others. Results are generally reliable within a defined range of conditions.
3. Low: Suggests that the method may be sensitive to changes in input parameters, assumptions, or conditions. Results may vary significantly under different scenarios.

Scalability indicates a method's ability to handle large-scale analyses efficiently.

1. High: Scalable methods can be applied to complex systems or datasets without substantially increasing resource requirements.
2. Moderate: Reflects an intermediate level of scalability. The method is suitable for moderate-sized analyses but may face challenges when applied to larger or more complex scenarios.
3. Low: Suggests limitations in scaling the method to handle large or complex analyses. The approach may become computationally intensive or less practical as the scale of the analysis increases.

Resource Requirements imply that the method demands significant resources, including computational power, expertise, time, or data.

1. High: High resource requirements may limit the accessibility or applicability of the method.
2. Moderate: Reflects a balanced level of resource requirements. The method is manageable with standard resources and does not excessively strain computational, human, or data resources.

3. Low: Indicates that the method has minimal resource demands and can be applied with relatively modest computational power, expertise, time, or data.

4 Results

The following table summarizes the comparison of different approaches based on uncertainty, robustness, scalability, and resource requirements:

Table 2. Evaluating the approaches

Approach	Uncertainty	Robustness	Scalability	Resource Requirements
Agent-Based Model	High	Moderate	Moderate to High	Moderate to High
Econometric Models	Moderate	Moderate	Low to Moderate	Moderate
Input-Output Analysis	Moderate	Moderate	Moderate	Low to Moderate
Reinforcement Learning	Moderate	Moderate	Low to Moderate	Moderate to High
Surveys and Interviews	Moderate	Low to Moderate	Low	Low to Moderate
Scenario Analysis	High	Low to Moderate	Low to Moderate	Low to Moderate
Policy Analysis	Moderate	Moderate	Low to Moderate	Low to Moderate
Delphi Method	High	Low to Moderate	Low to Moderate	Low to Moderate

These ratings are intended for a general comparison. The appropriateness of each approach depends on the specific context and research objectives, yet the detail aimed with Table 2 is as follows:

High uncertainty is attributed to ABM due to its reliance on subjective judgments and assumptions about individual agent behaviors and interactions within a system [21]. ABM demonstrates moderate robustness as it can handle variations to some extent, but results may still exhibit sensitivity to changes in initial conditions or agent behaviors [2]. ABM is rated as moderate to high in scalability as it can be applied to complex systems without substantially increasing resource requirements [28]. Moderate to high resource requirements are associated with ABM due to its need for computational power to simulate numerous agents and interactions [29].

Econometric models are assigned moderate uncertainty as they rely on historical data and statistical methods, balancing deterministic outcomes and potential variations [11]. Like uncertainty, econometric models demonstrate moderate robustness, providing reliable results within a defined range of conditions, but may be sensitive to changes in

underlying economic factors [8]. Econometric models are rated low to moderate in scalability as they may face challenges when applied to larger or more complex datasets [32]. Moderate resource requirements are associated with econometric models, requiring standard resources for data collection, analysis, and interpretation [33].

Input-output analysis is rated as moderate uncertainty as it relies on historical data and sectoral interdependencies to predict economic impacts, acknowledging potential outcome variations [5]. Input-output analysis demonstrates moderate robustness, providing consistent results within a defined range of conditions but may be sensitive to changes in economic structures or external shocks [35]. Input-output analysis is rated moderate in scalability as it can handle moderate-sized analyses efficiently but may face challenges with larger or more complex datasets [36]. Low to moderate resource requirements are associated with input-output analysis, requiring standard resources for data collection and analysis [37].

Reinforcement learning exhibits moderate uncertainty as it involves iterative learning through trial-and-error interactions, incorporating a balance between deterministic strategies and adaptive behavior [8]. Like uncertainty, reinforcement learning demonstrates moderate robustness, adapting to changing environments while maintaining consistency in decision-making processes [13]. Reinforcement learning is rated low to moderate in scalability as it may face challenges with larger datasets or complex decision-making environments [14]. Moderate to high resource requirements are associated with reinforcement learning, requiring computational power for training data-intensive models [41].

Surveys and interviews demonstrate moderate uncertainty as they gather subjective opinions and insights from stakeholders, acknowledging potential response variations [42]. Surveys and interviews are assigned a low to moderate level of robustness as they may be influenced by biases or variations in respondent perspectives [43]. Surveys and interviews are rated as low in scalability as they may not efficiently handle large-scale data collection or analysis [44]. Low to moderate resource requirements are associated with surveys and interviews, requiring standard resources for data collection and analysis [45].

Scenario analysis is attributed to high uncertainty as it involves exploring multiple future scenarios based on different assumptions or conditions, acknowledging the inherent unpredictability of future events [46]. Scenario analysis demonstrates low to moderate robustness as it relies on the quality of scenarios created and may not offer precise predictions of future outcomes [47]. It is rated low to moderate in scalability as it may face challenges with large-scale scenario creation or analysis [39]. Low to moderate resource requirements are associated with scenario analysis, requiring standard resources for scenario creation and analysis [39].

Policy analysis exhibits moderate uncertainty as it evaluates the effectiveness of policies and interventions in achieving specific goals, acknowledging potential variations in policy outcomes [38]. Policy analysis demonstrates moderate robustness as it provides insights into the impacts of specific policies but may overlook broader changes or unintended consequences [34]. Policy analysis is rated low to moderate in scalability as it may face challenges with large-scale policy evaluations or analysis [31]. Low to

moderate resource requirements are associated with policy analysis, requiring standard resources for policy evaluation and analysis [30].

The Delphi Method is attributed to high uncertainty as it relies on expert opinions and iterative feedback, acknowledging the subjective nature of expert judgments [23]. The Delphi Method demonstrates low to moderate robustness as it converges on a range of potential impacts based on expert consensus but may be influenced by expert biases or subjective interpretations [19]. The Delphi Method is rated as low to moderate in scalability as it may face challenges with large-scale expert panel recruitment or data collection [27]. Low to moderate resource requirements are associated with the Delphi Method, requiring standard resources for expert panel coordination and data analysis [18].

5 Conclusions

In conclusion, tackling the economic implications of generative AI requires a multi-dimensional analytical approach due to its complex dynamics. Each methodology discussed offers unique advantages and limitations. Agent-based modeling (ABM) excels in simulating individual behaviors and emergent system properties, making it particularly apt for scenarios characterized by high uncertainty and moderate to high resource demands. Econometric Models offer a historical data-driven perspective, entailing moderate uncertainty and resource requirements. The input-output analysis provides insights into sectoral interdependencies with moderate uncertainty and relatively low to moderate resource demands. Reinforcement Learning (RL) integrates machine learning into decision-making processes with moderate uncertainty and resource needs. Surveys and Interviews offer valuable insights into stakeholder perspectives with moderate uncertainty and low to moderate resource requirements. Scenario Analysis effectively navigates uncertainty, although with a high level of uncertainty and low to moderate resource needs. Policy Analysis evaluates interventions with moderate uncertainty and resource demands. The Delphi Method adeptly manages high uncertainty with relatively low to moderate resource requirements. A selection of methodologies, guided by research goals and contextual considerations, ensures a comprehensive understanding of the economic implications of generative AI.

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Revolutionizing Military Communications with a Conceptual Blockchain Model for Enhanced Security and Trust

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Abstract. Communication is critical in the military sector where the integration of sophisticated tools becomes crucial to maintain operationality and flexibility. This paper investigates the integration of blockchain technology in military communications, focusing on a blockchain-based Short Message Service (SMS) application for the Portuguese Air Force. The aim is to enhance security, reliability, trust, and flexibility in military communication systems. A comprehensive methodological approach was utilized, based on the Design Science Research, incorporating an extensive literature review, an exploratory study of various blockchain solutions, and the development of a conceptual framework for the SMS application. Findings reveal that the application successfully addresses crucial aspects such as secure transmission, data integrity, user anonymity, and compliance with regulations like GDPR. The discussion highlights the transformative potential of blockchain in military contexts, emphasizing improved operational efficiency and secure data handling. In conclusion, blockchain technology is decisive in advancing military communication methods, offering a model that can be adapted to other defense sectors. This study contributes to the theoretical understanding of blockchain in military applications and provides practical insights for its implementation in secure communication systems, using Hyperledger.

Keywords: Blockchain Technology · Military Communications · Secure Messaging · Portuguese Air Force · Digital Transformation

1 Introduction

As global communication and technology continually evolve, integrating sophisticated digital tools becomes crucial for government bodies, particularly in the military sector. This paper explores the development of a blockchain-based Short Message Service (SMS) application designed for the Portuguese Air Force. It addresses the urgent need for secure, effective, and flexible communication methods in military environments enhancing security, ensuring the immutability of messages, providing anonymity, decentralization, and data integrity, while complying with regulations.

Digital transformation (DT) and Artificial Intelligence (AI) have significantly altered the operational dynamics of government organizations. With the rise of the digital economy, these entities have seen notable improvements in social governance mechanisms

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[1]. Cutting-edge technologies such as blockchain and AI have played a pivotal role in transforming governance, supply chain management, and employee innovation [2, 3].

Blockchain technology, recognized for its strength and security capabilities, has emerged as a crucial element in enhancing secure communication. Although specific studies on blockchain in military communication are limited, research in sectors like healthcare and finance provides indirect insights [4, 5]. These studies emphasize the potential of blockchain in handling sensitive information and ensuring data safety, integrity, and transparency–essential qualities for military communication.

The Portuguese Air Force's need for a secure SMS application arises from the requirement to manage sensitive information with the highest confidentiality, flexibility, and efficiency. While direct research in this field is limited, studies in healthcare and military contexts offer a basis for understanding the potential advantages of such an application [6, 7]. Secure messaging systems have demonstrated their effectiveness in enhancing communication and operational efficiency, which can be applied to the needs of government entities, the military, and particularly, the Portuguese Air Force.

This introduction lays the groundwork for an in-depth examination of the conceptual model for a blockchain-based SMS application based on the Design Science Research Methodology (DSRM) [8]. It analyses the potential effects, challenges, and wider implications of interacting blockchain technology in military communications. The following sections will delve into the literature review, exploratory study, and proposed model, and conclude with key findings and future research directions.

2 Literature Review

Recent research in military communications, particularly in the Air Force, has shown a significant shift towards the integration of advanced technologies for efficiency, security, and operational effectiveness. This paper [7] sheds light on integrating mobile technology into military training, emphasizing the feasibility of technical aspects in deploying mobile apps. This is a key to enhancing training and communication capabilities within the Air Force. Additionally, [9] conducted research in speaker recognition for military radio communications, underlining the necessity of precise identity checks to ensure safe and reliable communication, which is crucial for the Air Force. In a parallel manner, [10] contributed to the development of novel voice signaling protocols for tactical communication, focusing on improving coordination and response times essential in Air Force operations. The paper [11] investigated the use of group communication protocols within the Air Force, aiming for optimal information dissemination and coordination. These studies collectively indicate a positive direction in using technology to enhance communication systems in terms of effectiveness, security, and operational excellence.

In the field of SMS technology for military and government applications, significant advancements have been made in security and communication flexibility. In the paper [12] authors introduced the BVPSMS protocol, which provides crucial end-to-end security for military communications over insecure channels. Authors [13] demonstrated the potential of SMS Gateway technology in hierarchical systems, applicable in military and government contexts. Another paper [14] focused on the effectiveness of the 3DES encryption algorithm for SMS messages, emphasizing its efficiency in securing confidential military and government communications. These advancements exemplify the

evolution towards more secure and efficient SMS technologies that meet the stringent requirements of military and government sectors.

The potential of blockchain technology in revolutionizing communication security, particularly in areas requiring high data integrity, privacy, and trust, has been widely recognized. In the paper [15] authors proposed a blockchain-based model for secure peer-to-peer messaging, enhancing the role of blockchain in communication security. Paper [16] introduced a blockchain-based IoT framework, marking advancements in securing network communications in complex environments. Paper [17] raised concerns about vulnerabilities in Ethereum blockchain smart contracts, emphasizing the need for secure blockchain messaging. Paper [18] study explored how blockchain secures data through IoT nodes. Additionally, the paper [19] examined blockchain's application in trade supply chains, including its effectiveness in securing communication and data integrity. Hyperledger framework, along with its various platforms has established itself as a foundational element in the development of blockchain applications, demonstrating significant flexibility and robustness [20–24], specially Hyperledger Fabric, as a dynamic and powerful tool for creating secure, efficient, and scalable blockchain solutions, with transformative potential across diverse industries.

Integrating blockchain technology in the Portuguese Air Force's communication systems, particularly for SMS applications, presents a unique mix of potential benefits and challenges. Recent research provides valuable insights into both the innovative solutions offered by blockchain technology and the hurdles that need to be overcome. Paper [25] explored the use of blockchain for enhancing secure and scalable communication in UAV networks. Their findings can be extrapolated to the Air Force's communication needs, particularly the use of SMS applications. The integration of blockchain with advanced cryptographic methods in UAV networks offers a glimpse into the potential of blockchain in ensuring secure communication. The study [26] on securing data communication between Air Controller Towers and aircraft using blockchain technology is particularly relevant. This approach, which bypasses traditional Proof of Work mechanisms for greater efficiency, underscores the importance of blockchain in military contexts where data confidentiality and integrity are vital. Paper [27] presented solutions for UAV communication utilizing blockchain and 6G networks. This is especially pertinent to the Air Force's use of drones and other aerial vehicles, suggesting that blockchain can significantly enhance the security and efficiency of communications, including SMS technology. The introduction of a Byzantine fault tolerance consensus for drone-based applications by Paper [28] is noteworthy. This protocol, which offers scalability and minimal resource usage, is apt for secure communication in the Air Force, demonstrating blockchain's utility in complex communication networks. Paper [29] discussed using blockchain for classifying SPAM messages in SMS communications. This application is crucial in military settings where the integrity and security of messages are of utmost importance, showcasing blockchain's role in enhancing communication security. These studies collectively indicate that blockchain technology can provide robust solutions for secure and efficient communication in military settings. However, they also highlight the need to address specific challenges, such as scalability, energy efficiency, and the integration of sophisticated cryptographic methods.

Paper [30] suggested a framework that will assist adopters in adopting blockchain technology and streamlining DApps development. The enablers that constitute a blockchain tool for ID management, data storage, entity registration, and marketplace negotiations represent the author's statements, offering a holistic view of the technological processes and functional aspects of DApps. Regarding Software Architecture for Digital Twin DApps, the paper [31], specifically talks about construction industry software architecture for blockchain-based digital twin DApps, which becomes an insight into the critical industry problems, functional requirements, and non-functional requirements supported by the DApps while providing the technological processes and architectural design considerations.

3 Exploratory Study

Regarding blockchain integration in small and medium organizations, various blockchain solutions have arisen like Ethereum, R3 Corda [32], Kailedo, Amazon AWS, and Hyperledger [33]. Each one offers unique functionalities to apply different use cases, acting as a pure facilitator in this novel of digital transformation. Hyperledger Anon-creeds employ zero-knowledge proof capabilities to enhance privacy in verifiable credentials (VC). Hyperledger Aries is an all-encompassing toolkit for decentralized identity solutions and digital trust. It enables the issuing, storing, and presenting of verifiable credentials while preserving privacy. Hyperledger Besu [34] is an Ethereum client optimized for enterprise use supporting both public and private networks. It features multiple consensus algorithms such as Proof of Stake and Proof of Work among others. Hyperledger Bevel aids safe deployment and operation of DLT platforms. Cacti accelerates the setup process for secure, scalable DLT networks and facilitates onboarding new organizations into the network. Hyperledger Caliper measures and reports performance indicators for specified blockchain implementations including Hyperledger Besu and Fabric amongst others. Hyperledger Cello reduces the effort involved in creating, managing, and using blockchains by serving as an operational console running on various infrastructures. Hyperledger Fabric [35] provides a foundation with a modular architecture for developing applications or solutions permitting interchangeable components. Hyperledger Firefly acts as a speed-boosting open-source super-node empowering businesses to develop secure Web3 applications at an increased pace. Hyperledger Indi leverages distributed ledger technology to create reusable tools, libraries, and components for independent digital identities ensuring cross-silo interoperability. Hyperledger Iroha constitutes a user-friendly blockchain that can be easily incorporated into infrastructure or IoT projects necessitating distributed ledger tech. Hyperledger Sawtooth allows smart contracts to define applications for business rules separately from the core systems' underlying design by featuring flexible architecture. Table 1 represents all Hyperledger projects at the time, types, and key applications.

Table 1. Hyperledger projects type and key applications

Nr	Name	Tool	Library	DLS	Key Applications
1	Anoncreeds	X			Decentralized Identity. Verifiable Credentials
2	Aries		X		Decentralized Identity. Verifiable Credentials
3	Besu			X	General Purpose DLT
4	Bevel	X			Deployment Automation
5	Cacti	X			Cross-chain interoperability
6	Califer	X			Performance Benchmarking
7	Cello	X			Deployment Automation
8	Fabric			X	General Purpose DLT
9	Firefly	X			Connectivity/Integration Gateway
10	Indy			X	Decentralized Identity. Verifiable Data Registry
11	Iroha			X	General Purpose DLT
12	Sawtooth			X	General Purpose DLT
13	Solang	X			Solidity Compiler

4 SMS Dapp Conceptual Framework

An SMS blockchain-based application to be used in the Portuguese Air Force needs to guarantee trust for secure, effective, reliable, and flexible communication among diverse intervenient/actors. This DApp should meet the traditional usability required for communications while complying with the blockchain technology needs, which can be extended using in a mobile environment.

4.1 Functional Requisites

To develop and successfully run an SMS blockchain-based DApp in the Portuguese military Sector and specifically in the Portuguese Air Force, there are several important functional requirements, as follows. User Registration and Management: To ensure secure profile creation with distinct access based on roles. SMS Sending and Receiving: The System should enable the smooth sending and receiving of Messages. Blockchain Integration: Use Hyperledger fabric to record messages unchanging the integrity. Encryption and security: Implement end-to-end encryption for messages and a secure storage system for keys. Anonymity Options: Users should have the option to send messages anonymously if desired. Data Integrity and Auditing: Through consensus mechanisms, ensure data stays intact. Providing abilities to audit as well. Compliance and Data Protection: The app must comply with relevant data protection regulations, like GDPR. Administration and Monitoring Tools: Include tools to oversee network health and user activities. User interface: Create a user-friendly, responsive interface across various platforms. Scalability and Performance: Design the system keeping growth possibilities in

mind without compromising performance. Interoperability Capabilities: The ability to communicate effectively with external systems is crucial. Backup & Recovery System Creation: Regular backups of data are needed with a strong disaster recovery plan in place. Documentation and Help: The application should provide user guides and accessible in-app support. Decentralized Data Storage: Leverage decentralized storage solutions for data that does not need to be stored on the blockchain. Smart Contract Development and Management: Implement smart contracts to establish rules governing application functionalities. Consensus Mechanism Alignment: Ensure unison with the consensus mechanism of the chosen blockchain format. Network Synchronization and Latency: Carefully handle network synchronization matters, aiming for minimal latency. Gas and Resource Management: Manage transaction costs effectively and optimize interactions with smart contracts. On-Chain and Off-Chain Interaction: Seamlessly manage data transfers between blockchain technology and external systems. Decentralized Identity (DID) Management: Securely manage user identities while incorporating privacy benchmarks. Cross-Chain Compatibility: Ensure functional compatibility across multiple blockchain networks for increased flexibility. Blockchain Node Management: Securely manage nodes involved in blockchain networks consistently. Upgradeability and Version Control: Strategize how to introduce upgrades and manage different app versions without disruption to users or loss of data integrity. Real-Time Monitoring & Alerts: Monitoring performance levels and security issues concurrently. Deployment: The application should have a streamlined process for deploying changes without disrupting existing services or causing downtime. Predictive Analysis and Reporting: Implement tools that allow for trend prediction and the generation of comprehensive reports to aid in decision-making. Cost Efficiency: Design the application to minimize overhead costs while maintaining high-performance levels. Customer Support: Provision for robust customer service, ensuring swift and effective resolution of user-reported issues. Open-Source Compliance: The application, particularly if it uses open-source components, should ensure compliance with all relevant open-source licenses and norms.

4.2 Technological Requirement

To develop and The Technical requirements are the foundation of any development project that aims to be a robust, secure, and efficient system. These particulars are critical to crafting the architecture and implementation strategy for the blockchain-based SMS DApp.

Technology Stack Selection: Identifying these requirements helps pick suitable technologies, such as programming languages, blockchain platforms, databases, and user interface frameworks. System Architecture Design: Detailed requirements inform how different parts of the system should interact, directing data flow and integration for cohesive functionality. Performance Metrics Specification: Establish what benchmarks the application should meet concerning speed, capacity to handle data and users (scalability), and more. Security Protocols Establishment: These protocols define how to protect information and maintain user privacy through encryption standards and other security measures. Compliance & Standards Adherence: The system must comply with national regulations–especially crucial in blockchain endeavors. Resource Allocation Planning:

Understanding these factors enables efficient planning concerning servers, storage solutions, and network bandwidth–essentially what hardware and software resources are required. Testing & Quality Assurance Basis: Technical outlines serve as a blueprint for testing methods ensuring all aspects of the system perform reliably under various conditions. Deployment & Maintenance Guidelines: These elements set out methods for deploying new features or updates while outlining ongoing maintenance tactics to keep things running smoothly.

4.3 Basic Use Case Diagram for SMS App

At the most basic level, this DApp aims to send and receive messages, in a decentralized way. The use case diagram that follows outlines an SMS messaging application custom-built (Figs. 1 and 2).

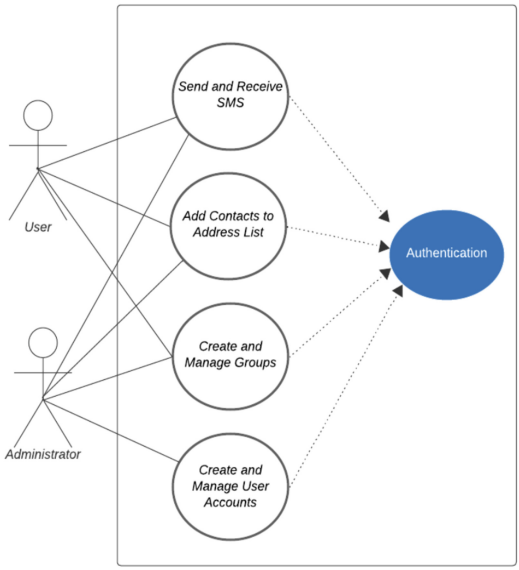

Fig. 1. A basic use case diagram for SMS App.

Users should be able to send and receive messages in this environment. In terms of adding contacts to an address list, thorough verification is necessary to prevent unauthorized communication. To maintain operational security, contact details should be encrypted. With regards to creating and managing groups, only authorized personnel should have access, controlled by their clearance level. Robust identity verification mechanisms can be supported using solutions like Hyperledger Indy. Authentication requires robust measures like multi-factor authentication (MFA) for all users to prevent unauthorized access.

4.4 DApp Implementation

As global communication and technology continually evolve, integrating sophisticated digital tools becomes crucial for government bodies, particularly in the military sector. This paper explores the development of a blockchain-based Short Message Service (SMS) application designed for the Portuguese Air Force. It addresses the urgent need for secure, effective, and flexible communication methods in military environments enhancing security, ensuring the immutability of messages, providing anonymity, decentralization, and data integrity, while complying with regulations. From the cross-references of functional and technical requirements of the SMS block-chain-based DApp with the Hyperledger solutions referenced in Table 1, it's possible to achieve that Hyperledger Foundation offers a variety of solutions that can leverage the implementation. Hyperledger Fabric offers capabilities for sharing data between multiple parties, updating the information programmatically, and applying governance controls to who can access that data. Hyperledger Firefly grants Connectivity/Integration Gateway empowering businesses to develop secure Web3 applications. The combined use of Hyperledger Fabric and Hyperledger Firefly can act as a bundle to provide the SMS exchange service. Hyperledger Fabric application domain, due to its modular capability can integrate Connectivity Application frameworks, SDKs, and Hyperledger Cacti, for example, granting a robust DApp with interoperability capabilities with other DLTs, which is crucial.

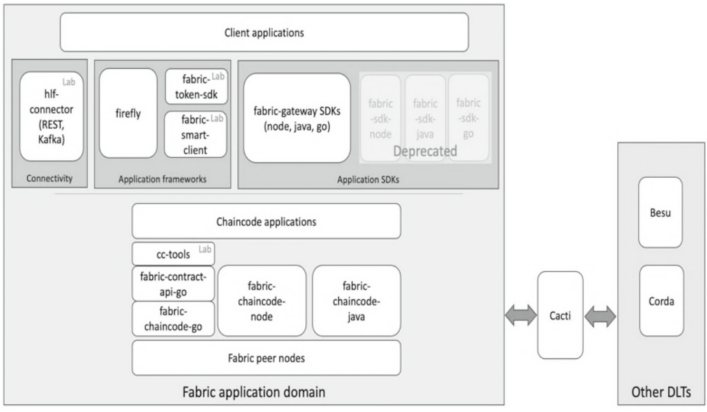

Fig. 2. Hyperledger Fabric ecosystem projects. [36].

The Application SDKs and Chaincode libraries allow the building of client applications written in Node, Java, or Go languages. Hlf-connector expose via REST service or Kafka messaging. Fabric smart clients act as a flow-based framework for writing blockchain applications that preserve privacy between transactors. Fabric token SDK assists in building token-based solutions on Hyperledger Fabric (uses Fabric Smart Client). Firefly is a complete stack for enterprises to build and scale secure Web3 applications and represents a crucial element in compilation. Hyperledger Cacti acts as a multi-faceted pluggable interoperability framework built on heterogeneous distributed ledger and blockchain technologies to run transactions spanning multiple networks [1].

5 Conclusions

An SMS blockchain-based application to be used in the Portuguese Air Force needs to guarantee trust for secure, effective, reliable, and flexible communication among diverse intervenient/actors. This DApp should meet the traditional usability required for communications while complying with the blockchain technology needs, which can be extended using in a mobile environment This study outlines how blockchain technology can revolutionize military communications, specifically within the Portuguese Air Force. The conclusions drawn from the paper refer to advances in military communications, integration of cutting-edge technologies, meeting security and operational needs while observing future potential and challenges and digital transformation implications. The development of a blockchain-based SMS application brings about major improvements in security, reliability, and efficiency for military communication systems. Key among the study's revelations is the successful integration of various advancements like Hyperledger Fabric and Firefly within the communication networks, reinforcing their potential to boost operational efficiency and security. Fundamental concerns such as secure data transmission, user anonymity, and data integrity have been effectively addressed using this blockchain-based SMS application. Compliance with stringent regulations like GDPR has also been underscored. This research has also indicated that blockchain technology, particularly within the Portuguese Air Force, could substantially boost operational security, reliability, trustworthiness, and transparency.

The theoretical implications of this work suggest a much broader horizon for blockchain's application than previously conceived. As our understanding shifts with this research, we see the technology's power extending beyond merely financial transactions toward transforming intricate military communication systems, ensuring enhanced security, reliability, and operational efficiency.

Practical implications of this work harnessing that blockchain technology for military communications has a real-world impact-making way for safer transmission of sensitive information, streamlined operations, assured confidentiality, and setting a strong foundation for the widespread implementation of this technology in various facets of defense endeavors.

Future studies are encouraged to further delve into this technology's potential role in different areas of military operations. For instance, validating the model proposed with a prototype developing the software accordingly, and integrating blockchain into chain logistics models during exercises and operations may streamline processes for improved efficiency. Blockchain's inherent transparency could enhance accountability across all activities in the Organizations. Other prospects include exploring Decentralized Identity (DID) and verifiable credentials to bolster security within identity verification-a critical element in military settings.

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Characterization of the Tobacco Tax

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Abstract. This study aims to characterize research on the special tax on tobacco, resorting to a systematic literature analysis. To this end, the Scopus database was used to find articles with the keywords "tobacco" and "taxation," published between 1943 and 2022, resulting in a total of 61 articles for analysis. After studying the articles found, it was possible to conclude that increasing the tax on tobacco is the most effective measure in reducing smoking. On the other hand, several authors also demonstrate that this measure may have negative consequences in certain countries, considering their structure, such as an increase in illegal trade, negative impact on the tobacco industry, and an increase in social inequalities. It was also found that studies related to this topic have been showing a growing trend, as it is a subject that affects public health and is constantly being updated.

Keywords: Tobacco · Taxation · Bibliometric · VOSviewer

1 Introduction

According to [16], tobacco kills more than 8 million people annually, among which 7 million are smokers and 1 million are passive smokers. It is also noteworthy that 80% of smokers live on incomes below the average, often foregoing basic needs to sustain this addiction. This dependency can also lead to chronic diseases such as tuberculosis, respiratory infections, and infertility, and furthermore, increase the occurrence of strokes and heart attacks.

Initially, tobacco taxation was used as a revenue generator; however, nowadays, most countries recognize this tax as a public health measure [5]. According to [23], poorer families tend to have a higher tendency for tobacco consumption, and consequently, as the tax included in this product is similar regardless of income, it is the most deprived families that suffer a greater loss. It is expected that with the increase in tax, a progressive policy will be witnessed, where lower-income families will tend to reduce tobacco consumption and, in the long run, contribute positively to public health.

[18] observe that more expensive cigarettes are associated with a lower likelihood of smoking, advocating that increasing taxes on them is the strongest policy to reduce smoking and consequently, the harmful effects on health.

In Portugal, the National Program for Prevention and Control of Tobacco Use (PNPCT) was created by the Ministry of Health on January 3, 2012, through Dispatch

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No. 404/2012, with the main objective of preventing and controlling tobacco use. For this purpose, several measures have been implemented, including increases in taxes on these products. It is noteworthy that, according to Article 3 of Decree No. 930/91, 1% of the fiscal revenue resulting from the tobacco tax aims to support actions against cancer, namely screenings, early detection, diagnosis, and treatment thereof.

2 Literature Review

2.1 Excise Taxes on Consumption

Taxes, besides their fiscal purpose, also serve an extrafiscal function as they contribute to wealth redistribution (the higher a taxpayer's income, the higher the applied tax, thus reducing inequalities), macroeconomic stabilization (tax variations help combat unemployment, economic stagnation, control inflation, and balance the balance of payments), and resource allocation (deductions, exemptions, and tax benefits influence individual behavior). Taxes also play a role in customs protection through protective measures.

According to [22], Excise Taxes on Consumption (ETC) and Value Added Tax (VAT) are crucial in addressing superfluous consumption. Unlike VAT, ETCs are selective, meaning they apply only to the consumption of goods considered harmful to the environment and public health, usually associated with items with greater financial potential [4]. In their legislation, it is noted that these taxes are subject to the principle of equivalence, meaning they should seek to "burden taxpayers, particularly in the areas of environment and public health," regardless of taxpayers' incomes.

In this context, this characteristic complements the extrafiscal aspect that characterizes these taxes, leading to greater repression of consumption of products adverse to society. [19] also notes that these taxes are "monophonic, subject to the Principle of Benefit and Equivalence," meaning the tax is applied once the product is introduced to the market and is applied in the same way to all consumers, based on the benefit received. This avoids companies having to bear these taxes and, consequently, financial burden, as recovery would only occur at the time of sale.

From a business perspective, an increase in Excise Taxes on Consumption can have serious financial impacts on companies that depend on the sale of products subject to this tax. If there is a drastic reduction in the turnover of these entities, it will be necessary to lay off people and may even lead to the bankruptcy of the company [17].

According to the study by [9], economists believe that excise taxes on consumption constitute a less distorted alternative to increasing state tax revenues. However, this tax makes the product's variation quite ambiguous and has a negative effect on wealth distribution, leading to more inequality. In other words, workers with lower incomes have to work more to maintain their consumption level.

2.2 Smoking

Many people start smoking during adolescence due to the problems they face, namely low socioeconomic status, reduced academic performance, and social influences [24]. Thus, [14] states that tax increases are effective in adulthood, but other interventions are

important to prevent tobacco use initiation in young people and adolescents. In these cases, measures such as banning smoking in more public places, banning advertising that encourages smoking, and emphasizing associated diseases [6] can be more effective.

USDHHS [20] states that adolescents are more sensitive to nicotine, becoming addicted to this substance more quickly than adults. From a statistical perspective, three out of four young smokers do not quit smoking when they reach adulthood, even if they intend to, and one-third of them will die prematurely due to diseases inherent in this habit.

[2] states that the increase in tobacco prices for consumers is higher than the increase in excise tax, contributing to higher state tax revenue than expected.

In the United States, according to the Monitoring the Future study, with data from 2005 to 2016, it is also concluded that tax increases are associated with lower tobacco consumption, regardless of gender, ethnicity, and education. However, it is observed that in 12th-grade students who intend to pursue higher education, there is a decrease in this consumption, which may be justified by parental education and a more fulfilling lifestyle [3].

The study by [3] argues that taxes do not reduce youth smoking, based on independent variables such as state cigarette taxes and the average cigarette selling price. Factors such as housing situation, employment, and annual poverty rate per state were also considered. The author analyzed data from interviews with 8th, 10th, and 12th-grade students, referring to parental education as a key indicator in the decision to smoke. It was found that when parents have university education, there is a lower probability of their children smoking.

Another important indicator is the intention to continue studies after the 12th grade; these students tend to value the future more, both in terms of health and monetary aspects. In other words, adolescents tend to follow the behavior of the adults around them, and the probability of smoking increases if there are people in their household who also smoke. In addition to this factor, the education they received and the environment they live in are vital to the adolescent's decision. Thus, it can be concluded that there is not enough evidence to assert that taxation is sufficient to reduce smoking in adolescence, as there are many factors that can lead to the initiation of this habit.

Contrary to the previously stated idea, the study by [11] states that tax increases are much more effective in young people than in other age groups. In Brazil, a 30% increase in tobacco prices led to a reduction in smoking from 15% to approximately 11% in 18-year-old smokers. In this context, the author argues that this measure reduces the likelihood of dependence on this product.

Also in East Africa, an increase in tobacco taxes was considered the best strategy to control smoking, as the majority of consumers belong to financially limited groups, including those under 18 years old. In contrast to the study by [3], this article states that tax increases are an effective measure even in smokers under 18 years old.

[21] shows that most of the population agrees with tax increases, provided that the resulting revenue is allocated to healthcare and contributes to the development of programs to discourage this habit.

[1] presents two interesting global perspectives; on the one hand, it argues that tax increases have a positive impact on consumer health, reducing inherent diseases and

consequently mortality rates; on the other hand, this tax can be seen as regressive, as the population with lower incomes will bear a disproportionate burden due to their reduced purchasing power.

In this sample, based on data from Ukraine, [8] take a contrary view to what was previously advocated. These two articles demonstrate that tax increases can lead to an increase in smuggling and consequently the illegal sale of products even more toxic than tobacco, also increasing criminal activities. It is also mentioned that some companies may not increase the final price to avoid a decrease in sales volume, meaning the tax increase may not be reflected in the final consumer and, therefore, may not have the intended effect. Similarly, to these researchers, [25], despite advocating for tax increases, warns of the possibility of the government not using the revenue from the tax increase for the proposed purposes but for its own benefit.

Currently, there is a trend to replace traditional or roll-your-own cigarettes with electronic cigarettes, necessitating an increase in taxation on these products as well to encourage quitting smoking. It is worth noting that heated tobacco is the newest additive, therefore, sufficient studies have not been conducted to predict its impact on the health of active and passive smokers, as argued by [15].

[13] argues that, on a global level, the best approach would be to apply a tax according to each country's structure. For this, it is relevant to analyze the elasticity of accessibility, considering the country's incomes and inflation. In addition to this measure, it can be concluded from the article by [12], based on data from Africa, that there are other fundamental measures, namely the prohibition of advertising campaigns for this product, banning consumption in enclosed spaces, prohibiting sales to minors under 18 years old, and promoting health warnings on tobacco packages to raise awareness among consumers of the potential diseases that this addiction can cause.

3 Methodology

Considering the defined research question, a quantitative methodology was adopted, as the main ambition is to characterize the existing literature on tobacco taxation. For this purpose, relevant literature framed within this theme was selected as the sample, through the choice of articles that meet a set of established criteria according to PRISMA, using 27 items and a four-stage flowchart. The main objective of this method is to ensure a transparent, comprehensive, and quality systematic review [10]. The first stage involves identification, where an initial search is conducted through a database, excluding duplicate documents. The second stage involves document selection, excluding those with characteristics that are not intended to be used. The third stage is eligibility, in which the eligibility of selected documents is verified according to pre-defined assumptions by the researcher. The fourth and final stage is inclusion, where documents of qualitative and quantitative synthesis are included, used in meta-analysis studies.

Thus, articles indexed in the Scopus database were selected, whose titles included the words "taxation" and "tobacco" up to 31/12/2022. Therefore, the search focuses only on English documents that encompass these words in the titles, obtaining related articles on tobacco taxation without biases, meaning specific articles on excise taxes on tobacco, as intended. After applying these filters, 90 documents resulted, from which only articles were selected, i.e., journals, notes, conference papers, books, and other undefined

documents were removed; in addition, unrelated titles, unrelated abstracts, and duplicate documents were excluded. After defining the keywords of the titles, inclusion and exclusion criteria, it was found that 4 articles are unavailable, resulting in a total of 57 articles available for this study. Regarding the variables that allow characterizing the selected sample, specific objectives were established, consisting of analyzing particularities at both the article and author levels. In this sequence, regarding the content of the articles, the following characteristics were discriminated: Article title; Type of research; Keywords; Year of article publication; Source where it was published; Number of source citations, as well as shared citations among them; Number of citations in articles and their evolution over the years; Thematic and geographical analysis of articles.

Regarding variables related to researchers, the following attributes were defined: Researchers' names; Authors' productivity; Country/continent of affiliation; Type of authorship; Citations between authors.

4 Results

4.1 Characterization of Article Content

Analyzing the type of research, it is found that the number of descriptive documents is equal to that of explanatory type, with each type of research accounting for 38.6% of the total sample, while the remaining 22.8% are exploratory. In the case of explanatory research, it is possible to understand how data from studies are obtained, and in this sample, most researchers used databases, followed by questionnaires, and lastly, case studies and interviews. It is noteworthy that the distinction between questionnaires and interviews is due to the type of questions and answers conducted by the researcher. On one hand, questionnaires consist of a set of questions (closed or open-ended), with answers usually being briefer since there is no interaction between the researcher and the respondent. On the other hand, interviews are more extensive, requiring more comprehensive answers from the interviewees, occurring in real-time and therefore conducted with a smaller number of people (Tables 1 and 2).

Table 1. Type of Research

Type of Research	Number	%
Descriptive	22	38,6%
Exploratory	13	22,8%
Explanatory	22	38,6%
Database	*10*	*45,5%*
Questionnaire	*6*	*27,3%*
Case Study	*3*	*13,6%*
Interview	*3*	*13,6%*

Regarding keywords, a bibliographic network was constructed, allowing visualization of the keywords of all articles, highlighting the most frequent ones and the relationships between them. For this purpose, a map based on Scopus bibliographic data submitted in the VOSviewer software was created. Subsequently, similar words were grouped, and the program selected the 10 keywords that appear in at least 3 articles, resulting in Fig. 1.

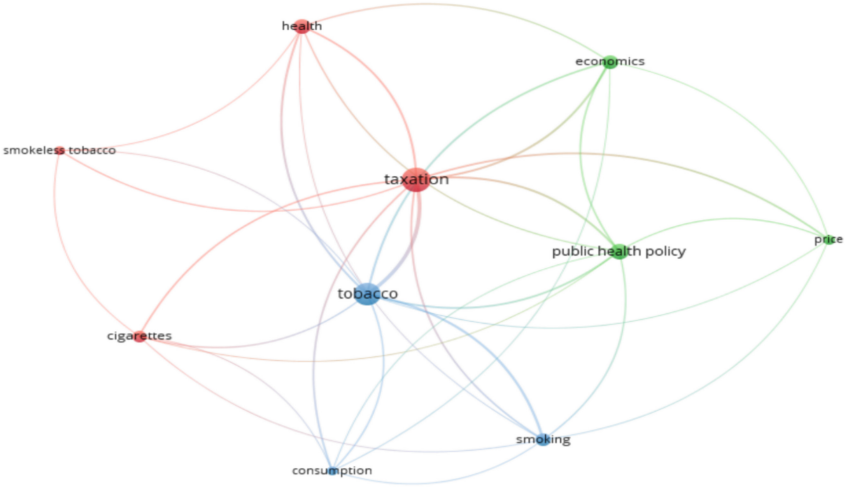

Fig. 1. Most Frequent Keywords.

Through this map, it is concluded that the most frequent keywords are "taxation" and "tobacco," with a fairly similar size, in accordance with the keywords defined for the article titles. Following are the keywords: "public health policy," "health," and "economics." These occurrences may be justified by the fact that some researchers consider tobacco taxation to directly influence the economy due to the behavior adopted by taxpayers. In turn, this behavior will also have consequences on their health, as it involves the consumption of a highly harmful substance. It is noteworthy that the proximity of keywords in the map reflects the relationship between them, the closer the clusters, the greater the connection between the words. In this case, "tobacco" and "taxation" are identified as the words with the greatest relation, as they are the main terms of this research and are addressed together.

In the study of the evolution of article publication over the years, there is a growing trend regarding research on tobacco taxation, but there is no regular trend. The period with the most publications occurred between 2019 and 2022, representing approximately 41% of the articles in the sample. Thus, it is concluded that there is an oscillation in article publication, although research on this topic is currently increasing, contributing to the growing trend in the evolution of the number of articles (Figs. 2 and 3).

Regarding the sources of this sample, it was observed that the articles were published in a total of 44 journals, of which only 7 had more than one article, with Tobacco Control having 12 registered publications, representing approximately 20% of the total.

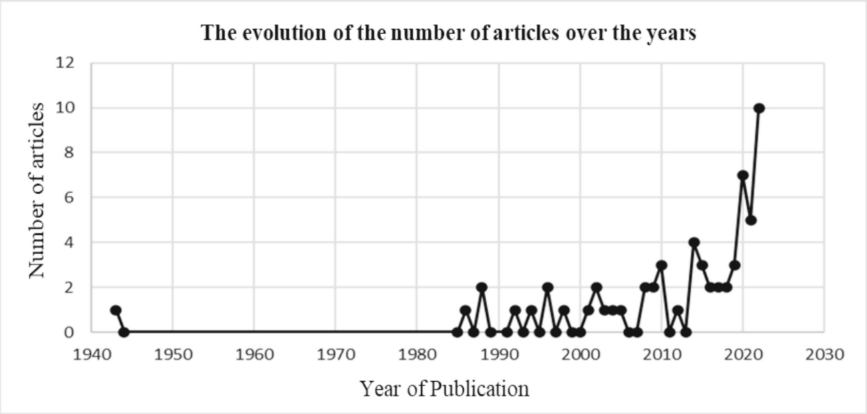

Fig. 2. Number of Articles Published per Year.

Table 2. Journals with 2 or more articles published

Journal	Number	%
Tobacco Control	12	19,67%
BMC Public Health	2	3,28%
Frontiers in Public Health	2	3,28%
Indian Journal of Cancer	2	3,28%
National Tax Journal	2	3,28%
Tobacco Induced Diseases	2	3,28%
Tobacco Prevention and Cessation	2	3,28%

4.2 Characterization of Authors

In this study, there are 191 authors responsible for the publication of the articles in the selected sample, of which only 17 researchers contribute 2 or more articles to this sample, meaning that the remaining 174 authors are responsible for the publication of only one article.

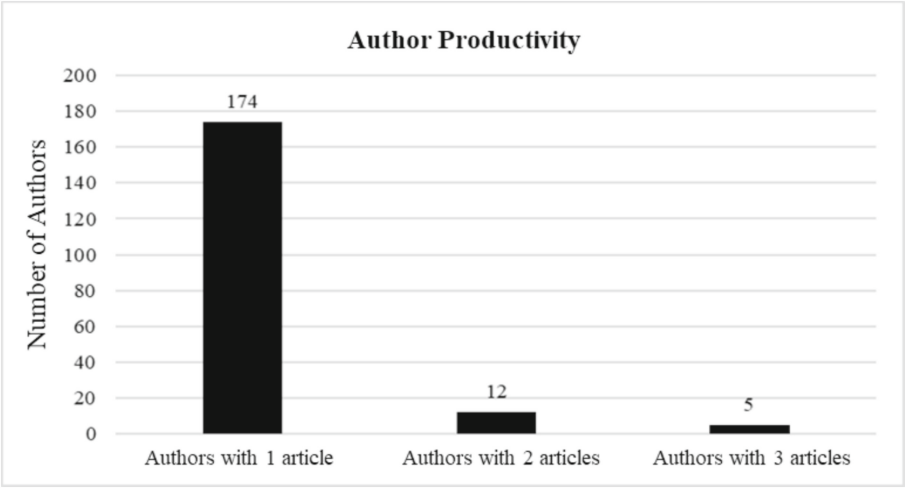

Fig. 3. Number of Articles Published per Author.

Regarding the geographical affiliation of the authors, according to [7], the most reliable way to know the country of residence of the authors is through educational institutions. It is noteworthy that in this sample, the total number of affiliations does not correspond to the number of researchers, as 5 of the authors have two countries of affiliation, meaning two study institutions to which they are linked. It was thus possible to ascertain that the most common country of affiliation is the United States of America, appearing in 44 authors, followed by Saudi Arabia with 14 and the United Kingdom with 11 authors. Regarding continents, they follow the same sequence as the countries mentioned earlier; that is, the most frequent continent is America, with approximately 34% of affiliated authors, followed by Asia (29.6%) and Europe (23.5%).

As for the type of authorship, it is observed that only 16% of the articles were authored by only one author. This means that in approximately 84% of cases, the type of authorship is collective, with the majority being articles with four or more authors. Specifically, there are 10 articles with one author, 17 documents with 2 authors, 7 articles with 3 researchers, and 27 articles with four or more researchers.

Regarding the number of citations associated with the researchers, it is observed that the most referenced authors are Nick Wilson (92 citations) and Teh-wei Hu (75 citations). However, there is no relationship between them, meaning that when using this program, it is observed that there is no map, as there is no connection between the clusters. Several authors are cited among themselves, with Frank J. Chaloupka being the author with the most connections and citations, with 77 citations. Thus, Fig. 4 reflects the 14 authors most cited among themselves, having at least 12 citations among them.

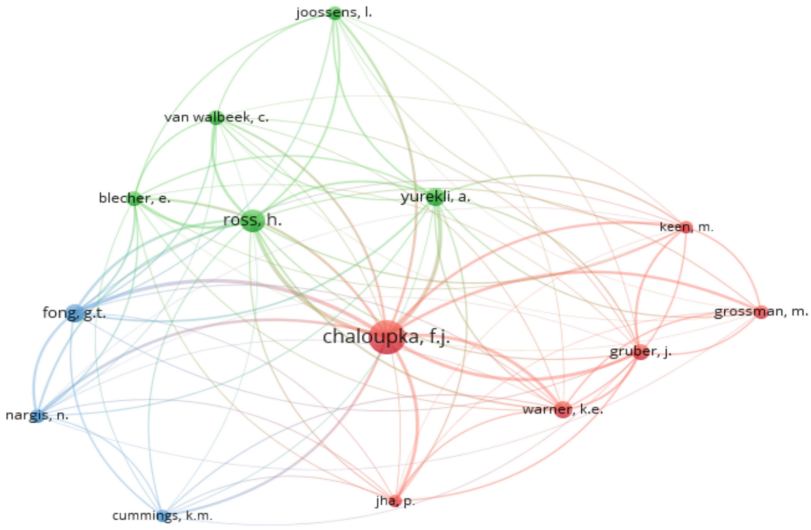

Fig. 4. Author Groups Citing Each Other.

5 Conclusions

The present study aimed to characterize the Special Tax on Tobacco, with two specific objectives, namely, describing the content of articles and characterizing the researchers. For this purpose, it was based on a sample of 57 articles collected from Scopus, covering a time period of 79 years, with the majority of the selected literature referring to the last 36 years.

Regarding the first specific objective, it is inferred that publications related to this topic are evolving progressively, with the year 2022 having the highest number of articles published (10 articles). The documents in the selected sample are disseminated in 44 different sources, among which Tobacco Control stands out as the dominant journal, publishing 12 of the articles. As for the most common keywords, "taxation" and "tobacco" emerge, naturally coinciding with the selected keywords. Regarding the thematic focus of the articles in this sample, it is concluded that the vast majority of articles focus on measures to reduce smoking, such as analyzing consumer behavior in response to tobacco tax increases. On the other hand, there are researchers discussing the impact of this increase on the tobacco industry and illicit trade, presenting different and relevant viewpoints.

After a comprehensive review of these articles, it is concluded that increasing tobacco tax is the most effective measure to reduce smoking. However, this increase should be above inflation and complemented with other measures, such as banning smoking in enclosed spaces, prohibiting advertising related to this product, and disseminating information about morbidity and mortality rates.

It is pertinent to adopt tax policies according to the structure of each country to prevent smuggling or substitution of this product for more affordable brands. For taxation to be effective, there needs to be harmonization of taxes on products harmful to public health, preventing the substitution of one additive for another cheaper one. That is,

this tax should follow a gradual increase and be applied to all tobacco products and brands, including electronic cigarettes. The reduction in accessibility to these products will decrease their consumption, especially among lower-income groups, who will be most affected by tax increases, as they will not have the means to sustain this addiction. Some researchers consider this unfair; however, with the mandatory decrease in tobacco consumption, individuals will end up buying less tobacco and consequently have fewer expenses related to tobacco-related diseases.

Regarding the second specific objective, authors Geoffrey T. Fong, Frank J. Chaloupka, Nigar Nargis, Nick Wilson, and Michael Kofi Boachie are the most productive, with each being responsible for 3 articles. It is also noted that authorship, for the most part, is collective, with 84% of the articles having two or more researchers. Concerning geographical affiliation, the most common is America (34%), with the dominant country being the United States of America (appearing 44 times). The most referenced authors in this research are Nick Wilson and Teh-wei Hu, with 92 and 75 citations, respectively.

Tobacco is a highly debated topic nowadays. In order to reduce its consumption, measures are increasingly sought to encourage its cessation. Thus, there is a trend of increasing the number of researches related to this topic, addressing not only the impact of tobacco tax but also other measures, such as health education. Overall, there is an increase in this tax, and consequently, a reduction in the percentage of smokers can be observed, establishing a negative correlation. In this sequence, this research contributes to knowledge about tobacco tax globally, as it is based on previously published literature, with data from all continents, mostly from the Asian and American continents. Through the summary of previous research, possible impacts on citizens' lives were identified, namely: an increase in social inequalities, as it is a tax applied equally to all taxpayers; unemployment in the tobacco industry if the sale of this product significantly decreases; the possibility of smuggling; and the substitution for cheaper brand products, eliminating the desired effect of the tax.

Thus, it is concluded that the best strategy to reduce smoking is to increase the special tax on tobacco and related products, according to the inflation and tax structure of each country. Therefore, by characterizing the existing literature in terms of article content and author information, this study contributes to the characterization of this tax, serving as a relevant instrument for future research. Furthermore, this research can play an important role in adopting measures to reduce smoking, as it considers various impacts that these measures can cause, depending on the structure of the country in question.

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Author Index

A
Abualgasim, Sally D. 108
Ahmed, Eshtiag Jahalrasool 108
Aparicio, Joao Tiago 27, 62, 496, 509
Aparicio, Mnuela 509
Araújo, Cristiana 134
Arsenio, Elisabete 496
Azevedo, Graça 311, 320, 348

B
Barbosa, Luis Arthur Rabelo 244
Barbosa, Sónia 282
Barreto, Adriana 469
Barros, Paulo 332
Barroso, Giovanni Cordeiro 423
Beirão, Gabriela 414
Bernardino, Carlos 522
Blas, Héctor Sánchez San 50
Borges, Victor Hugo 244

C
Cardoso, Alexandre 134, 423
Cardoso, Larissa Campos 244
Carlos, Moreno-Hurtado 388
Carnaz, Gonçalo 437
Carvalho, André 448
Carvalho, João M. 437
Castro, Gonçalo 294
Costa, Alberto J. 271, 282
Costa, Carlos J. 27, 62, 509
Cruz, Estrela F. 112
Cunha, Carlos R. 73, 85

D
da Costa Corrêa, Clarice 423
da Cruz, A. M. Rosado 112
da Rocha Fernandes, Anita M. 123
da Rocha, Tânia Vanessa Marques 163
da Silva, Amélia Ferreira 3
de Campos Amorim, José 16
de Figueiredo Marcos, Anabela Maria Bello 163, 358, 373
de Godoy Domingues, Rodrigo 244
de la Higuera Amato, Cibelle Albuquerque 401
de la Iglesia, Daniel Hernández 50
de Moura, Lucas Augusto Tavares 258
de Oliveira, Gabriel Henrique 244
de Sousa Uema, Vitor 401
Dias, Paulo 534
Dinis, Ana Arromba 174
Dinis, Ana 448
Diniz, Maria 484
Doménica, Espinosa-Campoverde 388
dos Santos, Clemilson Costa 423
Duarte, David 134

E
Eliseo, Maria Amelia 401
Esteves, Ricardo 282

F
Fernandes, Luiza B. 222
Ferreira, Adriana 212
Ferreira, Angel Rodrigues 134
Ferreira, Augusta 99, 235
Fujita, Rafael A. 222

G
Gabriela, Moreno-Hurtado 388
Gabriela, Paladines-García 388
Gaspar, Giovanna Lara Cabrera 244
Gomes, João Pedro 85
Gomes, Patrícia 469
González, Gabriel Villarrubia 50, 123
González-Mendes, Soraya 27
Graffunder, Felipe Canabarro 244

H
Henriques, Pedro Rangel 134

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Henriques, Rui 496

I
Inácio, Helena 99, 235

J
Jaguaribe, Daniel Rebouças 423
Jimenez, Diego Bravo 123
Jiménez-Bravo, Diego M. 50
Junior, Antônio Jose Melo Leite 423

L
Laureano, Raul M. S. 484
Leão, Ruth Pastôra Saraiva 423
Leithardt, Valderi R. Q. 123
Lima, Maria Adriana V. 134
Lima, Maria Adriana Vidigal 244
Lopes, Ana Isabel 294
Lopes, Renato Aquino 244
Lopes, Sérgio I. 112
Lopes, Sérgio Ivan 332
Lourenço, Clemente 150

M
Macedo, Alessandra Alaniz 222
Madaleno, Mara 39
Maldonado, Isabel 3, 16
Marques, David 461
Marques, Rui Pedro 437
Matias, Rodrigo 294
Mendonça, Vítor 85
Monteiro, Patrícia 348
Monteiro, Redney Manuel 73
Morais, Elisabete Paulo 73
Morais, Georgina 461
Moreira, André 73, 85
Morgado, Diogo 484
Mpinga, Valdo 112
Murciego, Álvaro L. 123
Murciego, Álvaro Lozano 50

N
Nunes, Liliana S. R. 271
Nunes, Pedro Emanuel Balhau 358, 373

O
O'Sullivan, Shane 174, 469
Oliveira, Helena Costa 16
Oliveira, Jonas 348
Osman, Abdalla Akod 108
Otoni, Guilherme Henrique Andrade 244

P
Penela, Daniela 294
Pereira, Beatriz Vidal 534
Pereira, Liliana 174, 448
Pinheiro, Margarida M. 187, 200, 212
Pinho, Carlos 3
Pinho, Márcio Sarroglia 258
Pinho, Sara 16
Portella, Daniella G. 222

Q
Quesado, Patrícia 469

S
Sampaio, Raimundo Furtado 423
Santos, Carlos 99, 235
Santos, Cláudia A. 187, 200
Santos, Guilherme Rodrigues 401
Santos, Sílvia Coutinho 174
Scaramuzzo, Talyta 401
Sereno, Luiz G. F. 222
Silva Zendron, Luis Augusto 123
Soares, José Marques 423

T
Tavares, Maria C 150, 311, 320
Teixeira, Milena Freitas 423
Toffoli, Guilherme Duarte 244
Torres, Ana 414

V
Vale, José 311, 320
Vianna, Filipi Damasceno 258
Vieira, Elisabete 39
Vieira, Rita 348
Vilela, Diogo 294