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AI, IoT, and the evolution of learning processes: A systematic review using a PESTEL perspective

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Abstract

The integration of Artificial Intelligence (AI) and the Internet of Things (IoT) into education is reshaping learning by creating more adaptive, interactive, and learner-centered environments. This study examines how these technologies influence education through the PESTEL framework, highlighting the political, economic, social, technological, environmental, and legal factors that shape their adoption. In fact, the choice of the PESTEL framework is based on its capacity to build a comprehensive macro-environmental analysis of the educational landscape. And using the PRISMA approach (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), the methodology includes a systematic identification of relevant studies, textual analysis of co-occurrences and author collaborations, and content analysis based on a structured analytical grid. The results indicate that political factors—such as government policies, national digital strategies, and public–private partnerships—play a pivotal role in enabling or constraining the implementation of AI and IoT in education. Economic considerations, social equity issues, technological readiness, environmental implications, and legal regulations also emerge as significant drivers. Overall, this review provides a comprehensive understanding of the multi-dimensional impact of AI and IoT on education and underscores the need for informed, forward-looking policies to support their responsible and effective integration.

Keywords: AI, IoT, learning, PESTEL, SLR

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1. Introduction

In recent years, the intersection of the Internet of Things (IoT) and Artificial Intelligence (AI) has exerted a major impact across various industries, with education being one of the most affected. This shift goes well beyond just technological upgrades—it carries significant social, economic, political, environmental, and legal implications, which we can explore through the PESTEL framework. It is crucial to understand the far-reaching effects of these technologies to truly grasp how they are reshaping the learning experience.

AI technologies, like machine learning and natural language processing, are enabling more personalized learning by adapting educational content to fit individual students' needs. At the same time, IoT devices are gathering real-time data, offering teachers invaluable insights into student engagement and performance. Together, these technologies are creating a more interactive and adaptable learning environment, ultimately leading to better educational outcomes.

This review, therefore, will be organized into three main sections: first, we will dive into the creation of the PRISMA diagram (Preferred Reporting Items for Systematic Reviews and Meta-Analysis); second, we will analyze the body of work by examining how authors collaborate and by categorizing the studies thematically; and third, we will conduct a content analysis.

The goal of this systematic literature review is to explore how IoT and AI are influencing education through the lens of the PESTEL framework. By reviewing the existing literature, this study seeks to identify both the opportunities and challenges these technologies bring, with a particular focus on their influence on educational policies, institutional structures, and societal expectations. Ultimately, this research will offer valuable insights into how AI and IoT are not just transforming the learning process, but also reshaping the broader educational landscape.

2. Methodology

The justification for using a Systematic Literature Review (SLR) in conducting a literature review stems from its rigorous and structured methodology for synthesizing existing research. SLRs follow a predefined process that minimizes bias and enhances the reliability of findings through the systematic identification, selection, and analysis of relevant literature. This approach enables researchers to identify trends, gaps, and inconsistencies, thereby providing a comprehensive understanding of a given topic.

Furthermore, SLRs promote transparency and reliability, allowing other researchers to reproduce the review process and build upon its findings. By adhering to established guidelines such as PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), SLRs contribute to the advancement of knowledge by offering a solid foundation for future research and evidence-based decision-making.

In fact, we executed PRISMA six times, once for each component of PESTEL: Political, Economic, Social, Technological, Environmental, and Legal (Table 1).

The search queries were conducted across 11 databases: Scopus, Science Direct, Web of Science, JSTOR, Cairn, IEEE, Springer, Google Scholar, MathSciNet, Research4Life, and DOAJ, with the following search strings:

- ("AI" AND "IoT" AND "PESTEL" AND "EDUCATION")
- ("AI" AND "IoT" AND "POLITICAL" AND "EDUCATION")
- ("AI" AND "IoT" AND "ECONOMIC" AND "EDUCATION")
- ("AI" AND "IoT" AND "SOCIETAL" AND "EDUCATION")
- ("AI" AND "IoT" AND "TECHNOLOGICAL" AND "EDUCATION")
- ("AI" AND "IoT" AND "ENVIRONMENTAL" AND "EDUCATION")
- ("AI" AND "IoT" AND "LEGAL" AND "EDUCATION")

Through the process of cleaning and filtering using the reference management software Zotero, we completed the PRISMA table (Table 3).

First, we removed duplicate articles and those missing essential information, such as abstracts, author names, or publication dates. Second, we eliminated articles with anomalies identified through a quick review of the “Info” and “Tags” sections. At this stage, we found 18 articles that addressed the research topic and were available in full text. It should be mentioned as a noteworthy fact that after grouping the results of all the queries, we removed duplicate records and obtained 12 quantitative articles.

- **For the query: ("AI" AND "IoT" AND "POLITICAL" AND "EDUCATION")**

Science Direct provided 658 open-access documents out of 1,682. Springer offered content primarily in English, with 476 documents available. The disciplines covered included economics, with 205 documents, and political science and international relations, with 271 documents.

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Table 3. *PRISMA for each component of PESTEL*

	Query	*("AI" AND "IoT" AND "PESTEL" AND "EDUCATION")*	*("AI" AND "IoT" AND "POLITICAL" AND "EDUCATION")*	*("AI" AND "IoT" AND "ECONOMIC" AND "EDUCATION")*	*("AI" AND "IoT" AND "SOCIETAL" AND "EDUCATION")*	*("AI" AND "IoT" AND "TECHNOLOGICAL" AND "EDUCATION")*	*("AI" AND "IoT" AND "ENVIRONMENTAL" AND "EDUCATION")*	*("AI" AND "IoT" AND "LEGAL" AND "EDUCATION")*
Identification	*Scopus*	0	9	21	21	175	68	12
	WOS	0	7	4	5	57	82	7
	Science Direct	17	658	393	206	415	402	196
	JSTOR	35	0	0	0	0	0	0
	Cairn	0	0	0	0	0	0	0
	IEEE	0	2	2	1	0	0	0
	Springer	35	476	58	24	59	52	54
	Google Scholar	10	10	10	10	10	10	10
	MathSci Net	0	0	0	0	0	0	0
	Research 4 Life	0	4	5	0	12	0	0
	DOAJ	0	0	0	0	0	0	0
	TOTAL	**97**	**1166**	**493**	**267**	**728**	**614**	**279**
	Duplicate records removed	20	48	4	4	30	29	5
	Records marked as ineligible by automation tools	34	193	25	11	32	1	1
	Records removed for other reasons	27	267	16	26	93	111	62
Screening	**Records screened**	**16**	**658**	**448**	**226**	**573**	**473**	**211**
	Records excluded	0	0	0	0	0	0	0
	Reports sought for retrieval	**16**	**658**	**448**	**226**	**573**	**473**	**211**
	Reports not retrieved	13	447	331	165	429	433	142
	Reports assessed for eligibility	**3**	**211**	**117**	**61**	**144**	**40**	**69**
	Reports excluded (out of scope)	3	210	113	59	142	36	64
Included	**Studies included in review**	**0**	**1**	**4**	**2**	**2**	**4**	**5**

- **For the query: ("AI" AND "IoT" AND "ECONOMIC" AND "EDUCATION")**

ScienceDirect had 393 open-access documents in English across various subjects, including economics (49 documents), social sciences (88), decision sciences (178), and psychology (78). For Springer, we have arranged the documents by relevance and selected the first two pages (58 documents) out of 561 documents in English, with economics (349) and education (212) being the dominant fields. Research4Life had five documents in English in economics, education, and philosophy.

- **For the query: ("AI" AND "IoT" AND "SOCIETAL" AND "EDUCATION")**

Science Direct returned a combination of papers and book chapters in open access from economics, decision sciences, psychology, and social sciences subject areas (206 documents). For Springer, we sorted and took the first two pages owing to their pertinence (24 documents) out of 214 documents written English in economics (129 documents), political science, and international relations (85 documents). For Research4Life, all the indexed 73 documents were restricted.

- **For the query: ("AI" AND "IoT" AND "TECHNOLOGICAL" AND "EDUCATION")**

Science Direct presented open-access book chapters and articles in areas such as economics, decision sciences, and social sciences (415 documents). For Springer, the results were sorted by relevance up to two pages (59 documents) over 589 documents written in English, with economics (349) and education (240) being their main areas of focus.

- **For the query: ("AI" AND "IoT" AND "ENVIRONMENTAL" AND "EDUCATION")**

ScienceDirect provides open-access book chapters and articles in decision sciences, social sciences, and environmental sciences (402 documents). For Springer, we sorted and took the first two pages owing to their pertinence (52 documents) over 589 documents in English that address economics, education, and interdisciplinary subjects in sciences, humanities, and social sciences.

- **For the query: ("AI" AND "IoT" AND "LEGAL" AND "EDUCATION")**

Science Direct offers open-access articles and book chapters in decision sciences and social sciences (196 documents). Springer also offers open-access content in English covering

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economics, education, and multidisciplinary studies in humanities and social sciences, which we sorted and took the first two pages owing to their pertinence (54 documents), over 258 articles and chapters written in English.

For all the queries, the articles obtained from Google Scholar were taken from the first two pages of results due to their relevance.

3. Results

3.1. Co-occurrence Analysis

Using the VosViewer software, we constructed a words cloud of keywords from the articles obtained through PRISMA. This words cloud allows us to analyze the occurrence of terms through keyword counting, which in turn enables a presentation of the corpus and a textual analysis.

As a first observation, the most frequently used words ‘art education and ‘digital teaching’ as they have the largest surface area (occurrence). Given that, there is one color which means one cluster of terms that contain all the items (Figure 5).

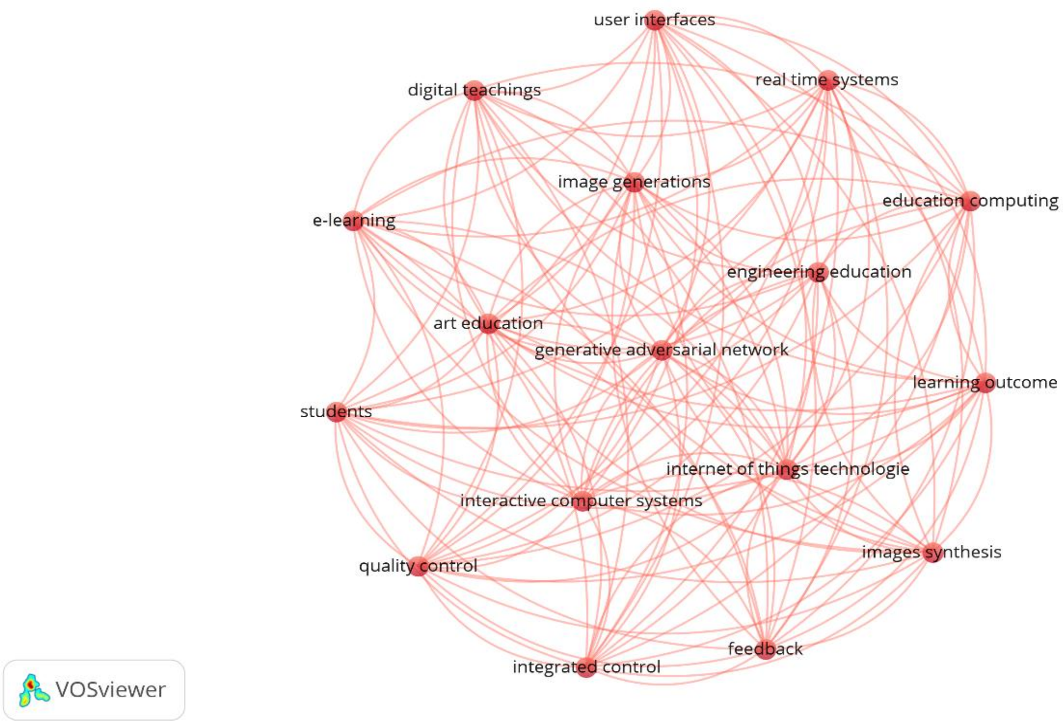

Figure 5. *Vosviewer network visualization of keywords and co-occurrences*

The density visualization highlights the extent of activity and scientific output. Our findings suggest that researchers are primarily focused on real-time systems (Figure 2).

As for Figure 3, it shows the appearance date of one cluster. We can deduce that researchers have recently started addressing the themes related to digital teaching and especially generative adversarial network.

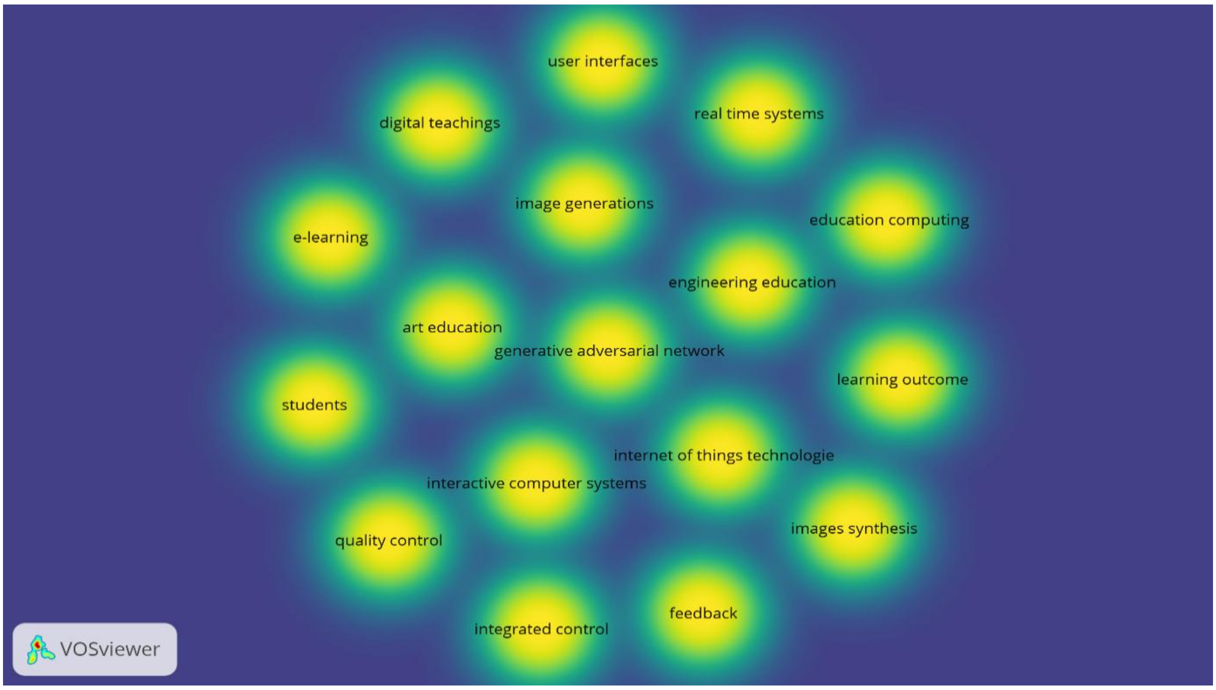

Figure 6. *Keywords density map via Vosviewer (Density visualization)*

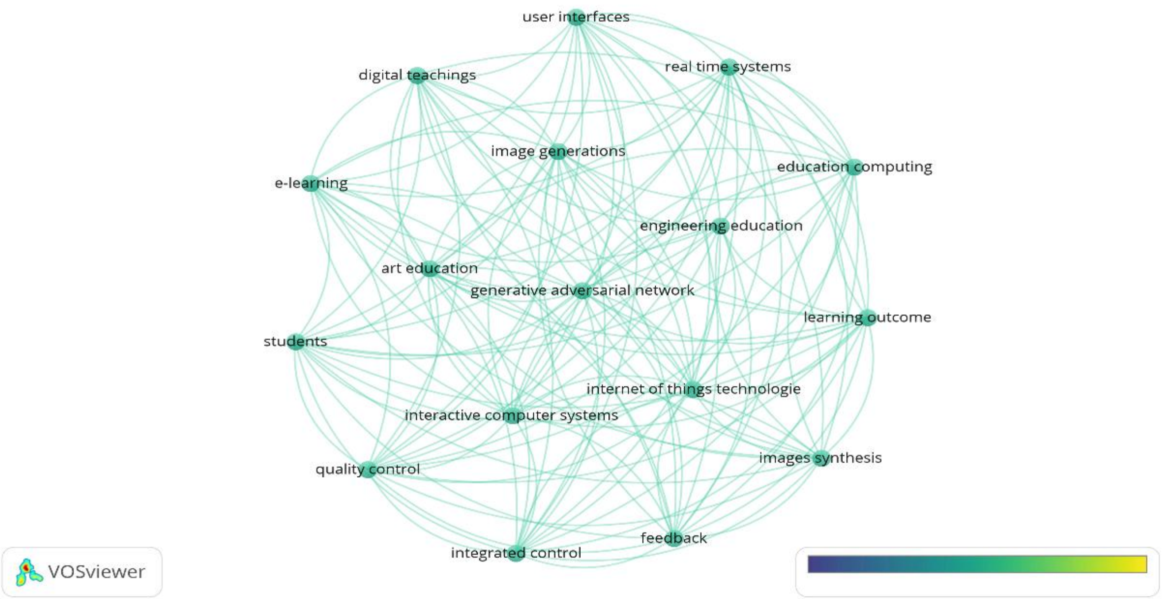

Figure 7. *Keywords Map and Their Appearance Dates via Vosviewer (Overlay Visualization)*

3.2. Analysis of co-authorships

Using the VosViewer software, we created a map of collaborations between authors. Upon initial observation, we noticed that all authors are represented by circles of the same size, suggesting a similar level of scientific productivity. Furthermore, we observed that the authors form a single cluster, indicating that they work together in research teams (Figure 4).

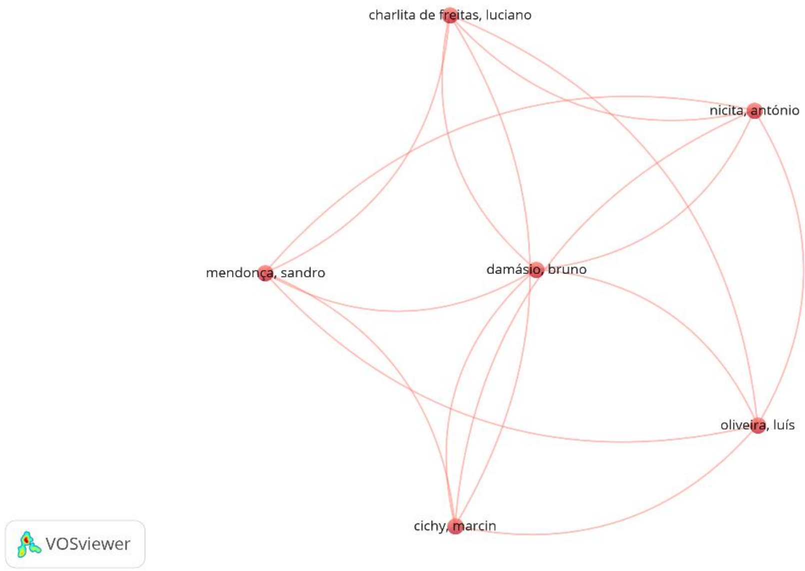

Figure 8. *Collaboration Network Map between Authors via Vosviewer (Network Visualization)*

Based on the graph of the collaboration network visualization between authors, we can see that each of the six authors has formed five collaborations with other researchers, creating a single cluster of authors. This observation is also supported by the density visualization graph, which illustrates the activity and scientific output of all the authors (Figure 5, Figure 6).

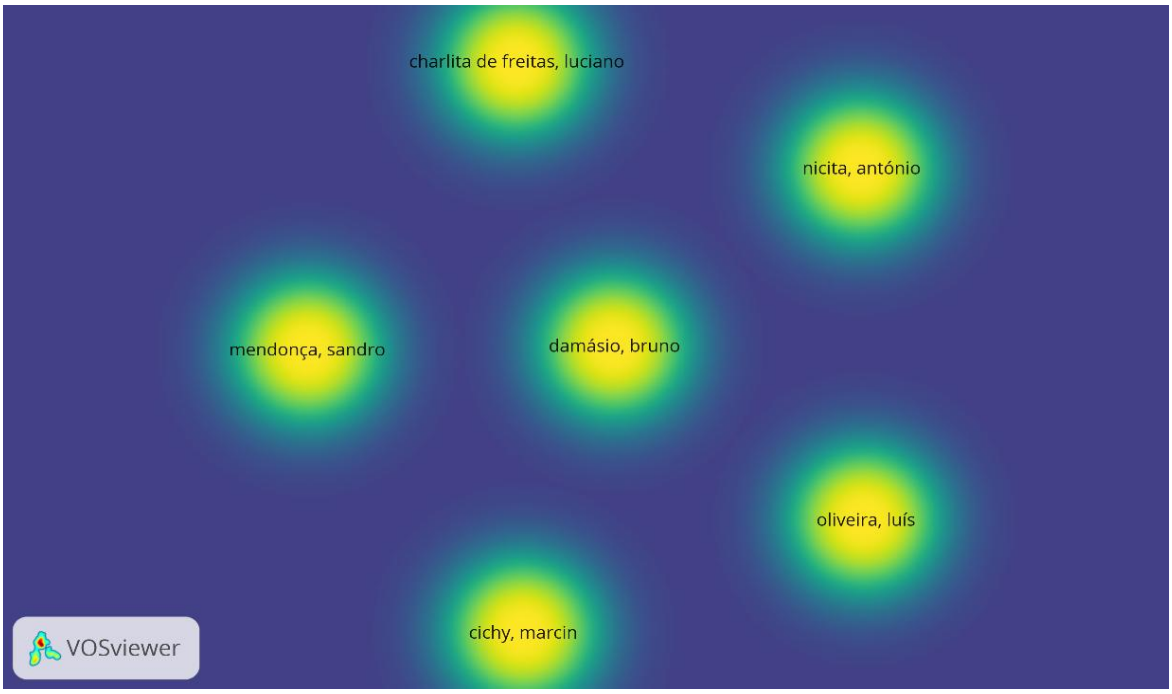

Figure 9. *Density Map of Authors' Scientific Output via Vosviewer (Density Visualization)*

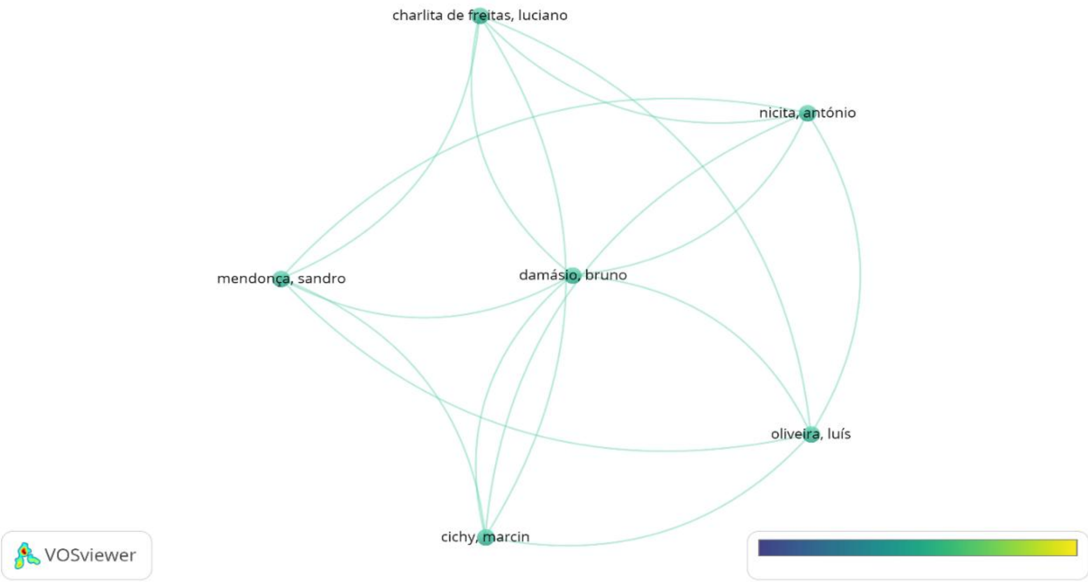

Figure 10. *Chronological Map of Author Collaborations via Vosviewer (Overlay Visualization)*

3.3. Exploratory Statistics

Based on the characteristics of the scientific journals selected by PRISMA using NVivo software, the majority of the works were published in 2024, and they were from Science Direct, Springer, Scopus, and Web of Science (Figure 7).

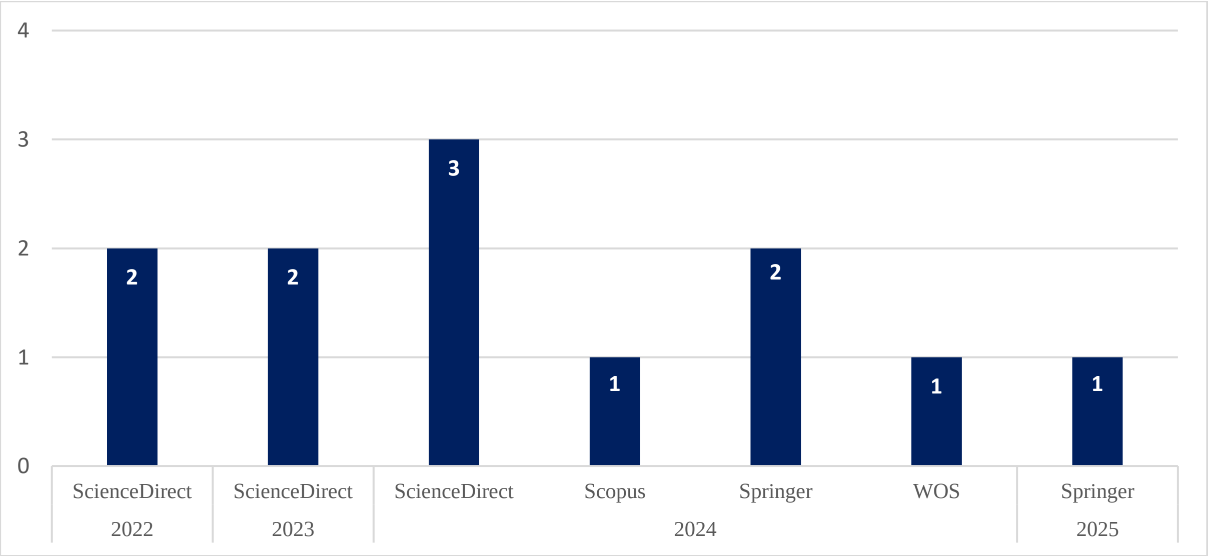

Figure 11. *Annual Evolution of the Number of Articles Obtained via PRISMA by Database*

In our analysis, we came across seven articles from ScienceDirect, three from Springer, and two from both Scopus and Web of Science. It is worth mentioning that the distribution was not entirely even, but that is pretty much, what we expected given the scope of our research (Figure 8).

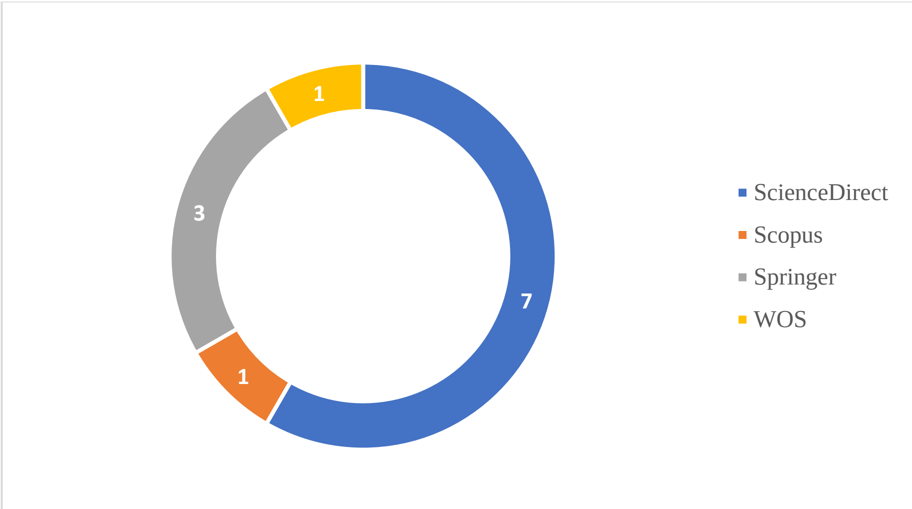

Figure 12. *Evolution of the Number of Articles Obtained via PRISMA by Database*

3.4. Thematic classification

The word frequency analysis in NVivo unveils a common set of 995 words used across the different articles. Notably, ‘education’ emerges as the most prevalent term (25 occurrences), trailed by 'study' (25) and ‘intelligence’ (18). As a result, NVivo proves to be a valuable resource for pinpointing constraints and patterns by examining linguistic consistencies across diverse studies (Figure 9).

Figure 13. *Visualization of the most frequent words cloud via NVivo*

To scrutinize deeper into the analysis, the analysis grid below presents the sources according to their problematic, research subjects, methods, and findings. This framework allows for a clearer comparison and understanding of how different studies approach similar or related topics, facilitating a comprehensive evaluation of their contributions to the field (Table 2).

Table 4. *Thematic Classification and Content Analysis (Analysis Grid)*

Authors	ISBN/ ISSN	Problematic	Research Subject	Research Method	Research Findings
(Saba & Monkam, 2025)	0972-5792, 2199-6873	Role of AI, tax revenue, and institutional quality in BRICS-Plus economic growth.	Impact of tax revenue, institutional quality, and AI on economic growth in BRICS-Plus countries (2012-2022).	Cross-Sectional Augmented Autoregressive Distributed Lag model with Cobb-Douglas framework.	AI-tax revenue interaction promotes growth, but AI-institutional quality link is weaker. Policies should foster AI-friendly institutions.
(Kim et al., 2024)	2662-9992	AI-driven job insecurity affects workplace sustainability and pro-environmental behavior.	Impact of AI-induced job insecurity on organizational sustainability in South Korea.	Three-wave time-lagged survey of 391 employees.	AI job insecurity affects pro-environmental behavior through psychological contract breach. Ethical leadership can mitigate negative effects.
(Alaeifar et al., 2024)	2214-2126	Challenges in sharing Cyber Threat Intelligence (CTI) among organizations.	CTI sharing benefits, applications, and challenges.	Comprehensive survey and analysis of CTI sharing architectures.	Proposed future research directions to improve CTI sharing.
(Kruger & Steyn, 2024)	0040-1625	Challenges and opportunities of the Fourth Industrial Revolution (4IR) in enhancing innovation capabilities in African universities.	Innovation mechanisms in university ecosystems.	Case study with cross-sectional data over six months.	Makerspaces support collaborative innovation and design phase activities.
(Chatterjee & al., 2023)	0040-1625	Adoption of non-market strategies by digital platform-based enterprises.	Non-market strategies of platform-based multinational enterprises (MNEs).	Survey of 11 MNEs and PLS-SEM analysis.	Non-market strategies enhance firm performance via knowledge sharing and coordination.
(Deighton & al., 2024)	0957-7572, 1573-1804	Lack of understanding of Industrial Design education.	Value and relevance of Industrial Design education in Australia.	Surveys and interviews with educators and stakeholders.	Recommendations for aligning Industrial Design education with 21st-century competencies.

Authors	ISBN/ ISSN	Problematic	Research Subject	Research Method	Research Findings
(Lai & al., 2024)	2666-6510	Challenges of Legal Large Language Models (LLMs) in the judicial system.	Applications and limitations of LLMs in law.	Comprehensive survey of LLMs and their applications.	Proposed future directions to address data, algorithm, and judicial practice challenges.
(Qiu & al., 2023)	2666-920X	Teachers' perceptions of the metaverse in education.	Use of the metaverse for innovation and entrepreneurship education.	Questionnaire-based study in China and Spain.	Found the metaverse in its experimental phase; highlighted potential for skill development and international cooperation.
(Zhang & Song, 2024)	24588989	Impact of air pollution and environmental hazards on human health and sustainable architecture.	IoT-enabled environmental toxicology platform and sustainable design in rural China.	Path analysis of 326 architects' data and simulation analyses.	IoT-AI platform outperforms traditional methods; Lisu building techniques correlate strongly with sustainable architectural practices.
(Fang & Jiang, 2024)	21693536	Enhancing art education with IoT and AI technologies.	Integration of IoT and GANs in art education.	Experimental evaluation using WikiArt dataset and performance comparisons with DCGAN and VAE.	IoT-GAN system outperforms others in image quality, speed, and student learning outcomes, achieving high satisfaction and engagement.
(Mendonça & al., 2022)	0308-5961	Evolution of 5G technology and its global impact.	Development and growth of 5G research.	Analysis of over 10,000 publications.	Identified key milestones in 5G research, with a "take-off" around 2014, offering insights for engineers and policymakers.
(Sanusi & al., 2022)	2666-920X	Lack of AI education for children in African contexts.	AI literacy competencies among Nigerian secondary school students.	Structural equation modeling using data from 605 students.	Highlighted the importance of teamwork and collaboration in AI literacy; no significant differences across gender or school type.

4. Discussion

The integration of the Internet of Things and Artificial Intelligence into education is nothing short of a paradigm shift. This goes far beyond just technological progress; it is about rethinking how we learn and teach in fundamental ways. In this discussion, we will look at the broader implications of these technologies through the PESTEL framework, considering not just their transformative potential but also the challenges they bring along with them.

4.1. Political Implications

The political conversation around AI and IoT in education highlights the need for solid policy frameworks. As these technologies continue to evolve and expand, there is a growing urgency to create regulations that protect student data privacy and security. Governments need to set clear rules to make sure AI algorithms are used ethically, especially when it comes to reducing bias and ensuring fairness in educational assessments. As schools and universities embrace these new tools, policymakers must also listen to different stakeholders to tackle issues of equity and accessibility, making sure that all students, no matter their background, can benefit from these advances.

4.2. Economic Considerations

From an economic standpoint, the implementation of AI and IoT in education offers the potential for significant cost savings and efficiency gains. However, achieving these benefits requires substantial investment in infrastructure, training, and ongoing maintenance. Educational institutions must carefully balance financial constraints while prioritizing technological integration. Additionally, these economic implications extend to the workforce, as educators must adapt to evolving roles as facilitators of learning rather than traditional knowledge transmitters. This shift calls for a reevaluation of teacher training programs so educators can gain the skills needed to effectively use AI and IoT.

4.3. Social Dimensions

Socially, the advent of AI- and IoT-enabled personalized learning holds considerable promise for enhancing student engagement and academic performance. However, it also raises critical concerns regarding equity. Disparities in access to technology may exacerbate existing educational inequalities, particularly among marginalized communities. To address this issue, educational institutions must implement strategies that ensure equitable access to AI and IoT resources. Additionally, fostering a culture of digital literacy is imperative, empowering both students and educators to critically engage with and navigate these technologies.

4.4. Technological Challenges

From a technological perspective, the integration of AI and IoT presents unprecedented opportunities for real-time data collection and adaptive learning environments. However, reliance on these technologies also introduces challenges, including concerns related to data integrity and the potential over-reliance on automated systems. Educators must strike a balance between utilizing technological tools and preserving the human element of teaching. Maintaining this equilibrium is crucial for fostering critical thinking and creativity—skills that are increasingly essential in the 21st-century learning environment.

4.5. Environmental Impact

From a technological perspective, the integration of AI and IoT presents unprecedented opportunities for real-time data collection and adaptive learning environments. However, reliance on these technologies also introduces challenges, including concerns related to data integrity and the potential over-reliance on automated systems. Educators must strike a balance between utilizing technological tools and preserving the human element of teaching. Maintaining this equilibrium is crucial for fostering critical thinking and creativity—skills that are increasingly essential in the 21st-century learning environment.

4.6. Legal Frameworks

The legal landscape surrounding AI and IoT in education is continuously evolving. As educational institutions adopt these technologies, they must navigate complex legal issues related to data protection, intellectual property rights, and compliance with educational regulations. Ongoing legal oversight is necessary to safeguard student rights and ensure that educational practices align with regulatory frameworks. Collaborative efforts between educational institutions, legal experts, and technology developers will be essential in fostering a responsible and legally compliant educational environment.

In summary, looking at the intersection of AI and IoT with education through the PESTEL framework reveals a landscape that's both full of potential and riddled with challenges. To make the most of this transformation, we need to take a holistic approach that considers the political, economic, social, technological, environmental, and legal angles. Through collaboration and open conversations between educators, policymakers, and technologists, we can make sure that AI and IoT are used to build a more equitable and effective education system. Moreover, of course, further research is needed to dig deeper into these areas, ensuring that these technologies align with the broader goals of educational equity and excellence.

5. Conclusion

This systematic literature review delves into the powerful impact that the Internet of Things (IoT) and Artificial Intelligence (AI) are having on the learning process, through the lens of the

PESTEL framework. Our analysis shows that, while these technologies have the potential to enhance educational practices, they also bring about a range of challenges and consequences across political, economic, social, technological, environmental, and legal aspects.

From a political perspective, incorporating AI and IoT into education calls for strong policies to safeguard data security and privacy. Economically, while these technologies can lead to greater efficiency and cost savings, they also require significant investments in infrastructure and training to make them work effectively. On the social front, there is huge potential for personalized learning, but we cannot ignore the issues of equity and access—especially since unequal access to technology could worsen existing educational gaps. Technologically, the combination of AI and IoT offers exciting new possibilities, such as real-time feedback and adaptive learning environments. However, this also raises valid concerns about becoming too dependent on technology and losing the traditional methods of teaching that many still value. Environmentally, as we move more toward digital solutions, we need to consider their sustainability—not just in terms of how we deploy technology, but also the ecological footprint that comes with it. Legally, the ever-changing landscape of educational tech requires ongoing attention to ensure it complies with regulations and, importantly, protects student rights.

In conclusion, adopting AI and IoT in education requires careful thought and consideration. Policymakers, educators, and tech developers must navigate these complexities with a critical eye. Only by understanding the broader implications of these technologies can we create a more equitable and effective learning environment for the future. Moreover, there is still plenty of research to be done to explore these areas more deeply, making sure that the integration of AI and IoT ultimately serves the best interests of the educational sector.

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Disclosure Statement

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