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Curricular Innovations for AI and IoT: A Systematic Review of Educational Challenges and Opportunities (A2.2)

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Abstract: This systematic literature review (SLR), conducted with the support of CiteSpace tools, investigates the integration of Artificial Intelligence (AI), the Internet of Things (IoT), and curriculum development to meet the demands of Industry 4.0 and Industry 5.0. The analysis highlights key trends and challenges in aligning academic curricula with the rapidly evolving technological and industrial landscape.

The review emphasizes the importance of preparing academia for emerging technologies by integrating AI, IoT, and edge computing into curricula to ensure that graduates are equipped for the next industrial revolutions. Additionally, the focus on building technological competence in students underscores the need for universities to combine theoretical knowledge with practical skill-building to address real-world industrial challenges. The findings call for strategic planning in ICT education, advocating for systematic curriculum development that aligns with emerging industry needs while fostering an integrated approach to education and research. Furthermore, the study highlights the growing significance of human-centric solutions in the digital era, reflecting the need for ethical and socially responsible approaches to technological advancement.

The TransLeader project (2023-2-PL01-KA220-HED-000179445) supports these findings through its innovative curriculum, which combines technical proficiency with leadership training. The project's activities, including this SLR (Activity A2.2) and dissemination of results (Activity A3.7), contribute to shaping IT leaders capable of navigating digital transformations and fostering competitiveness across Ukraine and the EU.

Keywords: artificial intelligence (AI); Internet of Things (IoT); curriculum development; Industry 4.0; ICT education

Innowacje programowe w zakresie sztucznej inteligencji i Internetu rzeczy: Systematyczny przegląd wyzwań edukacyjnych i możliwości (A2.2)

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Streszczenie: Niniejszy systematyczny przegląd literatury (SLR), przeprowadzony z wykorzystaniem narzędzi CiteSpace, bada integrację sztucznej inteligencji (AI), Internetu Rzeczy (IoT) oraz opracowywania programów nauczania w celu sprostania wymaganiom Przemysłu 4.0 i Przemysłu 5.0. Analiza wskazuje kluczowe trendy i wyzwania związane z dostosowywaniem programów akademickich do szybko zmieniającego się krajobrazu technologicznego i przemysłowego.

Przegląd podkreśla znaczenie przygotowania środowisk akademickich do nowych technologii poprzez integrację AI, IoT i edge computing w programach nauczania, aby absolwenci byli odpowiednio przygotowani do wyzwań kolejnych rewolucji przemysłowych. Zwraca również uwagę na budowanie kompetencji technologicznych wśród studentów, co wymaga łączenia wiedzy teoretycznej z praktycznymi umiejętnościami, aby sprostać rzeczywistym wyzwaniom przemysłowym. Wyniki badania wskazują na konieczność strategicznego planowania w edukacji ICT, postulując systematyczne opracowywanie programów nauczania dostosowanych do potrzeb przemysłu oraz promowanie zintegrowanego podejścia do edukacji i badań naukowych. Ponadto, podkreślono rosnące znaczenie rozwiązań skoncentrowanych na człowieku w erze cyfrowej, co odzwierciedla potrzebę etycznych i społecznie odpowiedzialnych podejść do postępu technologicznego.

Projekt TransLeader (2023-2-PL01-KA220-HED-000179445) wspiera te wnioski poprzez innowacyjny program nauczania, łączący wiedzę techniczną z umiejętnościami przywódczymi. Działania projektu, w tym niniejszy SLR (Działanie A2.2) oraz upowszechnianie wyników (Działanie A3.7), przyczyniają się do kształtowania liderów IT zdolnych do zarządzania transformacjami cyfrowymi i wspierania konkurencyjności w Ukrainie i Unii Europejskiej.

Słowa kluczowe: sztuczna inteligencja (AI); Internet Rzeczy (IoT); programy nauczania; Przemysł 4.0; edukacja ICT.

1. Introduction

The TransLeader project (2023-2-PL01-KA220-HED-000179445) is an ambitious initiative aimed at developing an innovative curriculum for IT business leaders in industries heavily influenced by artificial intelligence (AI) and the Internet of Things (IoT). As technology evolves rapidly, the demand for skilled professionals who can lead businesses in a technology-driven economy has grown. This project responds to that need by designing a comprehensive curriculum that not only integrates cutting-edge technological expertise but also focuses on leadership and management skills critical for the success of future IT business leaders.

One of the key activities of the TransLeader project is to evaluate and align educational practices and curricula with the emerging needs of the digital economy. As part of this effort, the systematic literature review (SLR) serves an essential role. The SLR aims to explore the current state of research related to AI and IoT education, identifying trends, gaps, and best practices. By analyzing academic sources, the SLR helps create a foundation for the design of an industry-relevant curriculum that prepares students to tackle future challenges in both AI and IoT fields.

This review is part of the TransLeader project's Activity A2.2, which focuses on mapping existing curricula and educational resources in the context of Industry 4.0 and 5.0 technologies. Through the SLR, we aim to identify the most effective approaches for embedding AI and IoT into educational programs, ensuring that students graduate with not only the technical competencies but also the leadership skills necessary to excel in the digital economy. Additionally, the SLR is linked to Activity A3.7, which focuses on sharing the outcomes of the project, including key findings from the curriculum development process, with a broader educational and professional audience.

By synthesizing existing research on AI and IoT curricula, this review contributes to shaping the future of IT leadership education. The results of this literature review will directly inform the ongoing development of the TransLeader curriculum, ensuring that it remains at the forefront of innovation, global competitiveness, and educational excellence.

2. Materials and Methods

The analysis spans the years 2017 to 2024, with notable variation in the volume of records across the timeline. The years 2022 and 2024 stand out with the highest activity, showcasing 14 and 11 works, respectively. Earlier years, such as 2017 and 2018, saw limited contributions, with just one and two works recorded, signaling the nascent stage of research within the domain. During the middle years of the period, from 2019 to 2021, research maintained a steady pace, reflecting consistent growth in scholarly interest and contributions.

The core dataset analyzed consists of 55 works selected from WoS database as a result of query ((TS=(artificial intelligence curriculum) OR TS=(AI curriculum)) AND (TS=(internet of things curriculum) OR TS=(IoT curriculum))), which are pivotal in the field, forming the backbone of the network and shaping its structure. These works are supported by a vast set of 2288 references, of which nearly all were valid, affirming the reliability of the citation data. Only a minimal fraction—about 1.8%—was deemed invalid, highlighting the robustness of the dataset. The primary composition of these references reveals the dominant presence of articles and proceedings papers, indicating a research landscape that thrives on both in-depth journal publications and dynamic conference interactions. Review articles further enrich the dataset, offering critical syntheses that underscore the maturity and thematic depth of the field.

The network derived from the core works features 188 nodes and 659 links, encapsulating the most influential connections among the larger body of references. These nodes represent significant references that provide foundational and cutting-edge contributions. The network's structure highlights co-citation patterns and thematic clusters, pointing to areas of convergence and critical intellectual intersections within the research community.

The analyzed works, along with their references, align with key themes that define the research landscape. Central topics include the integration of Cloud Computing, IoT, AI, and Industry 4.0 technologies into higher education curricula and industrial practices. These themes underscore a growing emphasis on aligning academic frameworks with technological advancements to prepare students for emerging professional landscapes. The research also highlights methodological approaches, such as deductive reasoning and curriculum matrix development, which aim to bridge the gap between academia and industry.

The funding landscape offers further insight into the global and regional dynamics of research. European Union programs, such as Erasmus+, feature prominently, reflecting a strong focus on collaborative education-technology projects. International agencies like the U.S. National Science Foundation and the Japanese Society for the Promotion of Science, alongside regional entities such as the Hellenic Foundation for Research and Innovation, underscore the diverse funding sources that support this field. This diversity highlights a shared global commitment to fostering innovation in education and technology integration.

Over time, the thematic focus of research has evolved. In the early years of the dataset, between 2017 and 2019, studies were foundational, exploring the potential of integrating emerging technologies into education and industrial systems. The mid-period, from 2020 to 2022, marked an expansion in research volume and a more pronounced alignment with the global momentum of Industry 4.0. By the later years, particularly 2023 and 2024, research took a more applied approach, focusing on actionable frameworks and curriculum redesigns that respond to the rapid technological transformations of the era.
In summary, this dataset captures a field in dynamic evolution, from foundational explorations to applied solutions. The 55 core works, supported by a dense network of references, reveal critical intellectual contributions and thematic progressions. Together, they provide a comprehensive lens into the interplay of education, technology, and industry within a rapidly changing global context.

3. Results

3.1. Clusters of keywords

Applying CiteSpace software, the results were obtained with the help of advanced cluster analysis. Based on keywords in the basic works of dataset and references the clusterization was performed (Figure 1 and 2). The most significant clusters are described below.

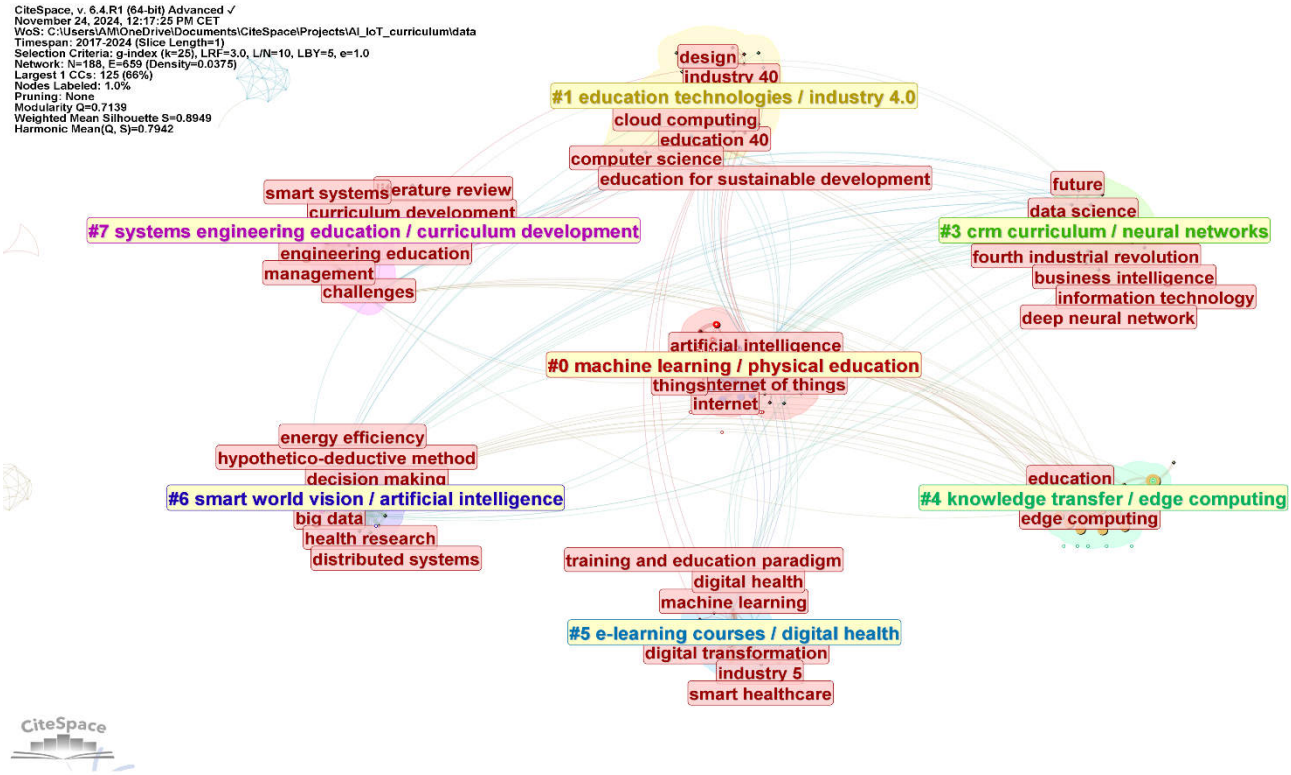

Figure 1. Clusters constructed according to keywords. The titles of the clusters are due to LSI/LLR measures

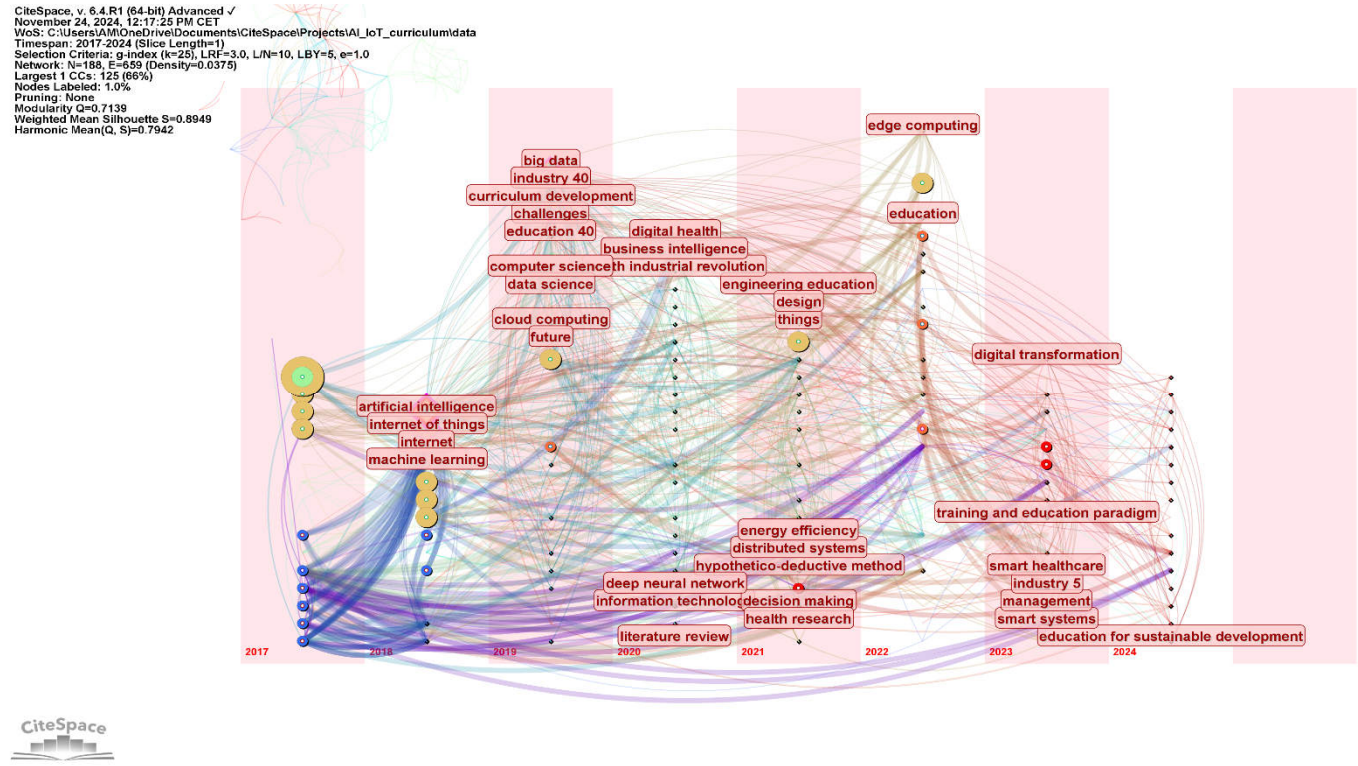

Figure 2. Time zones show the basic keywords along time

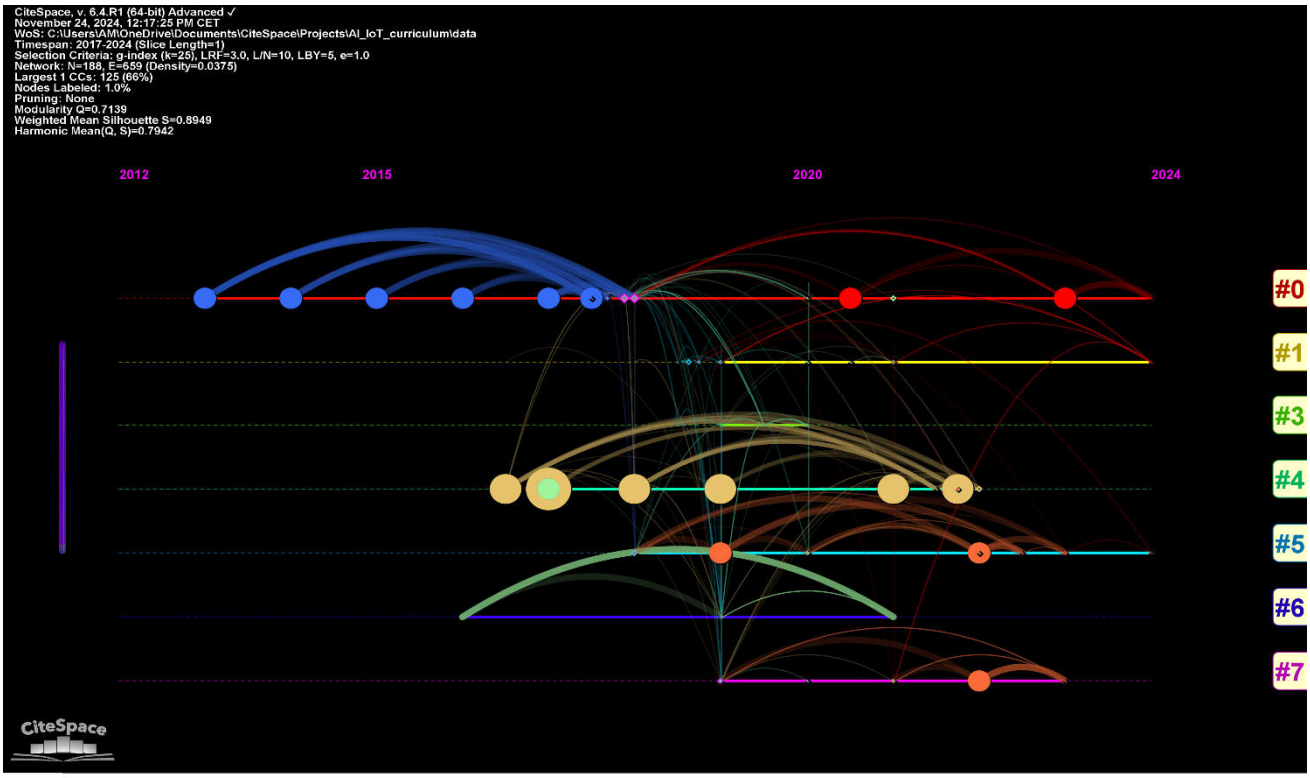

Figure 3. Time line plot show the clusters of keywords along time

Cluster #0: Preparing Academia for Emerging Technologies

This cluster focuses on the alignment between academic curricula and the evolving industrial demands shaped by emerging technologies such as artificial intelligence (AI), the Internet of Things (IoT), and edge computing. It emphasizes the need for academia to anticipate future trends in scientific research and industrial practices, ensuring students acquire the requisite skills for the fourth and fifth industrial revolutions.

Key insights include the importance of courses that address current and future industrial needs by incorporating AI, IoT, and edge computing technologies [1], and the necessity of preparing graduates for industrial markets through tailored curricula [2]. Additionally, the transformative potential of digital health education inspired by Industry 5.0 principles is noted [3]. Discussions also touch on how advanced AI technologies like deep learning can innovate fields such as physical education [4].

Cluster #1: Industry 4.0 and Educational Implications

Cluster #1 explores the transformative impact of Industry 4.0 technologies—automation, AI, IoT, and cyber-physical systems—on business and education. It highlights the challenges of developing a workforce skilled in advanced information technologies and data analytics [5] and underscores the significance of sustainable education initiatives, such as Education for Sustainable Development (ESD) aligned with global goals [5].

The cluster also identifies gaps in AI's integration into education, including its ethical implications, influence on Bloom's taxonomy, and strategies for collaboration between academia and industry [5]. Vocational training and technical education are highlighted as critical avenues for addressing these challenges [6], while cloud computing and related technologies remain underdeveloped in terms of industry-contextualized curricula [7].

Cluster #3: Digital Transformation Across Sectors

This cluster examines the concept of digital transformation (DT), particularly in traditional industries such as mining and customer relationship management (CRM). Digital transformation is defined as the process by which organizations adapt to modern technology, including AI, IoT, and big data [8]. The cluster highlights the steep learning curves industries face as they integrate these technologies [8], as well as the long-term success of industries dependent on a digitally skilled workforce [8].

A key area of focus is CRM innovation and the role of AI and IoT in transforming how businesses manage customer relationships, with insights derived from panel discussions and industry case studies [9]. The cluster also identifies gaps for future research on ICT-based innovations in vocational education and training [6].

Cluster #4: Building Technological Competence in Students

Cluster #4 concentrates on the role of universities in equipping students with the knowledge and skills necessary for industries adopting AI, IoT, and edge computing. This cluster highlights the results of surveys conducted among students and academics to evaluate the current state of university courses regarding IoT, AI, and edge computing [1].
It emphasizes how universities can play a pivotal role in preparing graduates for modern industries [2] by focusing on practical skill-building through activities such as lectures and hands-on sessions [10]. Discussions also stress the importance of addressing industry-identified gaps through academic interventions [2].

Cluster #5: Industry 5.0 and Human-Centric Approaches

This cluster introduces the concept of Industry 5.0, which emphasizes human-centric solutions and sustainable practices, building upon Industry 4.0 technologies. The cluster reflects on the acceleration of digital transformation during the COVID-19 pandemic and the necessity for innovative educational and industrial practices in healthcare [11].
Key themes include a new teaching and learning paradigm inspired by Industry 5.0 principles [3] and strategies to cultivate job-ready graduates through hands-on experience in advanced healthcare technologies [3]. Collaborative learning models are also highlighted as essential for preparing students for future industrial challenges [3].

Cluster #6: Strategic Planning for ICT Education

Cluster #6 addresses the strategic planning required to advance research and education in information and communication technologies (ICT). It calls for planning research and education through clear performance criteria, system models, and coherent curricula aligned with industry needs [12].
Discussions include the impact of cutting-edge technologies such as AI, augmented reality, and big data on student learning [13] and the need for an integrated approach to education and research [2]. The cluster also emphasizes the importance of bridging theoretical and practical applications in preparing graduates for the digital transformation of industries [8].

Cluster #7: Enhancing Knowledge Transfer in AI, IoT, and Cloud Computing

This cluster examines the role of academics in transferring essential skills and knowledge about AI, IoT, and edge computing. It highlights the increasing importance of these technologies across industries, particularly as foundational elements for technological advances [2].
Cloud computing is also discussed as a critical enabler of new educational methodologies, offering tools and infrastructure for technological advancement [14]. The cluster emphasizes the rapid evolution of AI and IoT as primary domains for both educational innovation and industrial application [14].

3.2. Analysis of the Timeline Plot

The timeline plot (Figure 3) provides a valuable perspective on the development and interconnection of research clusters over time. It highlights the shifting focus and activity levels of academic discourse surrounding AI and IoT education.
During the **2013–2018 period**, research predominantly concentrated on **Cluster #0: Preparing Academia for Emerging Technologies**. This reflects an early recognition of the need to align academic curricula with technological advancements such as AI, IoT, and edge computing. This foundational work set the stage for more specialized discussions and emphasized skill-building to address the demands of the fourth and fifth industrial revolutions.
In **2017**, the emergence of **Cluster #4: Building Technological Competence in Students** marked a shift towards evaluating university efforts to equip students with practical AI and IoT skills. Publications within this cluster served as a springboard for subsequent works in Cluster #0, with citation peaks in **2018–2019**. This suggests that the integration of hands-on educational methods was pivotal in informing broader strategies for preparing academia for technological changes.

Cluster #6: Strategic Planning for ICT Education, emerging in **2016**, provided a framework for systematic approaches to planning research and education in ICT. However, its relatively early contributions appear to have been overshadowed by later clusters with broader or more focused applications.

A significant nexus occurred in **2019**, with **Clusters #3–#7** demonstrating close interrelations. This period saw an intensified exploration of themes like **Digital Transformation (Cluster #3)**, **Human-Centric Approaches in Industry 5.0 (Cluster #5)**, and the importance of **Knowledge Transfer (Cluster #7)**. These clusters collectively underscored the importance of adapting both industries and education to digital realities, suggesting a convergence of interests across various domains.

As of now, **Clusters #0** and **#5** remain the most active, reflecting ongoing interest in equipping academia for technological innovation and fostering human-centric solutions aligned with Industry 5.0 principles. Their sustained activity underlines their relevance to current and future educational and industrial challenges.

Conversely, **Clusters #3, #4, and #6** exhibit diminishing activity. Their last publications appeared in **2020, 2022, and 2021**, respectively, indicating a decline in research attention. This may reflect a saturation of findings in those areas or a shift in priorities towards more dynamic clusters like #0 and #5.

The timeline plot, therefore, reveals a clear trajectory: the field's initial focus on aligning academia with technological advancements (Cluster #0) has evolved to emphasize human-centric and sustainable approaches (Cluster #5), while interest in clusters addressing narrower themes or strategic frameworks has waned.

This analysis provides insight into the dynamic evolution of AI and IoT curriculum research and its alignment with technological and educational imperatives.

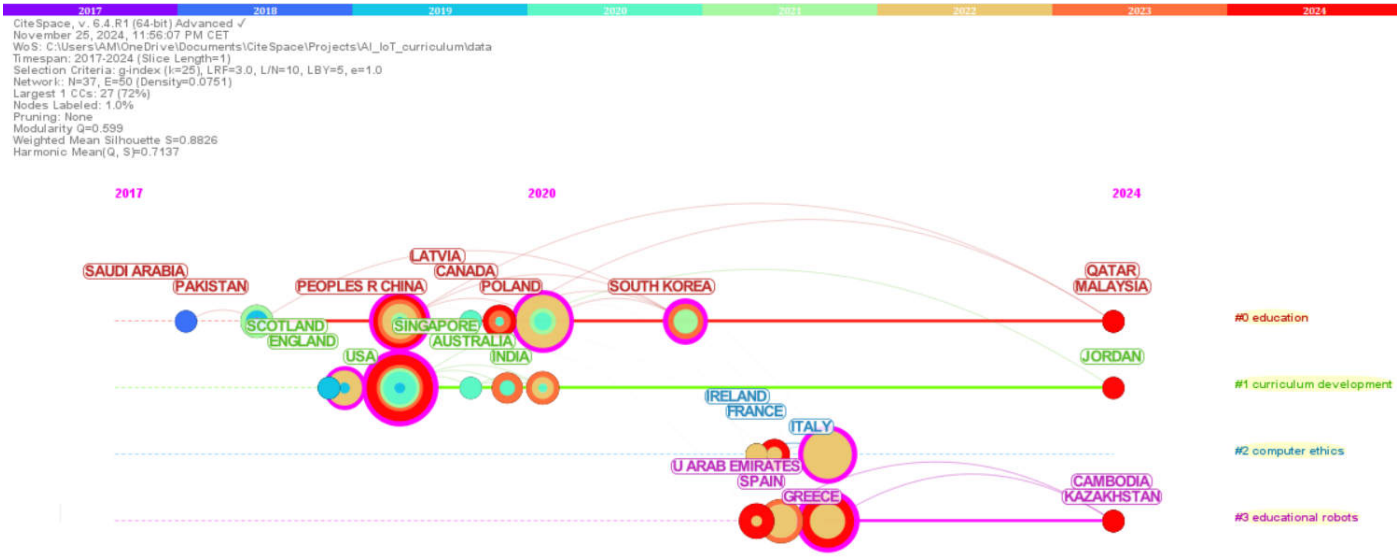

Figure 4. Timeline for the clusters constructed on countries

3.3. Timeline plot constructed for countries

The timeline (Figure 4) illustrates a globally interconnected narrative of technological integration in academia and industry. While some regions pioneered these efforts, others are leveraging them to address specific local needs, collectively advancing education and innovation.

The progression of works in cluster #0 reflects a global shift toward aligning academic curricula with technological advancements. Early contributions in 2017 from Saudi Arabia and Pakistan set the stage, followed by China's substantial input in 2019. Latvia, Canada, and Poland expanded this discourse in 2020, emphasizing global collaboration. South Korea (2021) and Qatar and Malaysia (2024) continued the focus on integrating AI, IoT, and edge computing into education, building on earlier works.

The cluster #1 demonstrates the worldwide recognition of Industry 4.0's educational implications. The United States led in 2019 with strategies to bridge academia and industry. By 2020, Singapore, Australia, and India contributed with regional perspectives on sustainable education. In 2024, Jordan provided further insights, emphasizing inclusive educational frameworks within Industry 4.0.

Italy's 2022 contributions highlight the role of workforce readiness in digital transformation (cluster #2), particularly in traditional industries like mining and CRM.
The UAE, Spain, and Greece initiated cluster #3 in 2022, focusing on educational strategies for AI, IoT, and related technologies. By 2024, Cambodia and Kazakhstan expanded the discussion to address regional challenges, demonstrating the cluster's growing relevance globally.

4. Conclusions

This systematic literature review (SLR) prepared with the help of CiteSpace tools [15, 16], explores the intersection of Artificial Intelligence (AI), the Internet of Things (IoT), and curriculum development, shedding light on how educational systems are adapting to the evolving demands of Industry 4.0 and beyond. Through comprehensive cluster analysis, several key trends and challenges emerged in the context of higher education and industry collaboration, particularly in relation to AI and IoT curricula.

The findings from the cluster analysis highlight the need for academia to align its curricula with the rapidly changing technological landscape. Cluster #0, "Preparing Academia for Emerging Technologies," emphasizes the necessity for curricula that integrate AI, IoT, and edge computing, ensuring that students are equipped with the skills required for the next industrial revolutions. This reflects the ongoing demand for a workforce capable of navigating the complex and interdisciplinary nature of modern technology-driven industries. Similarly, Cluster #4, "Building Technological Competence in Students," underscores the importance of universities focusing on practical skill-building activities, bridging the gap between theoretical knowledge and real-world applications.

The analysis further emphasizes the strategic planning needed to advance ICT education. Cluster #6, "Strategic Planning for ICT Education," calls for a systematic approach to curriculum development, ensuring that educational institutions not only align their programs with emerging industry needs but also adopt an integrated approach to education and research. This ensures that graduates are not just knowledgeable in specific technologies, but also equipped to drive innovation and manage digital transformations within industries.

Another significant cluster, Cluster #5, "Industry 5.0 and Human-Centric Approaches," discusses the growing importance of human-centric solutions in the digital era. This insight aligns with the broader objective of education systems to produce well-rounded leaders who can navigate the complexities of both technological advancements and the social implications of these innovations.

The TransLeader project, with its focus on preparing IT business leaders in industries shaped by AI and IoT, directly relates to these findings. Activity A2.2, which guided the systematic literature review, focused on identifying the best practices and curricular frameworks that integrate technical competencies with leadership and organizational management. By doing so, the TransLeader project aims to ensure that students are not only technically proficient but also capable of leading organizations in an increasingly digital and interconnected world. Moreover, through Activity A3.7, the project shares its findings, contributing to the global discourse on how to align educational curricula with Industry 4.0 demands, ensuring that the next generation of IT business leaders are well-prepared for future challenges.

In conclusion, this review underscores the critical need for curricula that incorporate emerging technologies such as AI, IoT, and edge computing, alongside leadership training and a focus on ethical, human-centric solutions. The alignment of educational standards across regions, particularly between Ukraine and the EU, as emphasized by the TransLeader project, further enhances the mobility and competitiveness of IT professionals. The holistic approach advocated by the TransLeader project ensures that future IT business leaders are not only capable of navigating the technical landscape but also equipped to lead organizations through the digital transformations that define the future of work and industry.

Disclaimer

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