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A look at Sustainability through the Lens of the Sustainable Development Goals and Education 5.0: A systematic Review of the Literature

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Abstract

We discuss a new construct called Industry 5.0, which has infiltrated the education sector, enabling us to explore Education 5.0. This concept is based on the use of advanced technologies that enable it to address global issues in contemporary society, many of which are related to sustainability. In line with the above, the aim of this research was to reveal the possible advances that have been made in Education 5.0 and its relationship with Sustainable Development Goals, especially sustainability, to achieve this, a systematic literature review was carried out, analyzing 92 articles from the Web of Science (WoS) and Scopus databases. The analysis was carried out through research questions that allowed the documentary corpus to be explored, organized, and segmented in order to focus on three elements How sustainability has been approached by Education 5.0, the possible challenges it faces in working toward sustainability in the immediate future, and finally, a characterization of the publications. The results take into account that: a) the management of education and its relationship with industry 5.0 seems to be the favorite topic when SDGs are addressed; b) the impact on sustainability for 5.0 technologies is diverse, ranging from facilitating intelligent resource management to refining teaching methods, raising awareness of sustainability, improving collaboration and promoting virtuality; c) SDGs is the topic less addressed in the literature in the margin of Education 5. 0; d) Most of the authors agreed that the main challenge is the widespread adoption of technologies in Education 5.0. The review concludes that the emergence of Education 5.0 introduces technological advances accentuated by a human-centered vision. However, it is urgent that institutions adopt an inquisitiveness about quality education, the achievement of SDGs, and the sustainability of education to amplify sustainable key competencies, such as creativity and human-centered thinking.

Keywords: *Education 5.0, Sustainability, Pedagogy in Society 5.0, Educational innovation, Higher education.*

Introduction

The transition into the 5th industrial era, termed Industry 5.0, has announced significant problems in various sectors, including higher education, where learners need to be adaptive, resilient to technological advances, and sustainable in their actions. This approach has been defined as Education 5.0 as an attempt to address present ongoing digital transformation and green transitions

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in universities (Carayannis & Morawska, 2023), as an education that goes beyond the application of technologies to enter into the field of ethics and humanism (Lantada, 2020), and as an education that nurture learners to be agents of their own professionalism with a global mindset (Alharbi, 2023). These definitions enable us to identify broader visions and opportunities for research in higher education, aligning their scopes with the demands of the new 5th industrial revolution. This approach not only aims to bring sustainability to education as the central core of these investigations but also to incorporate the intrinsic human factor.

Given that the 5th Industrial Revolution is the core that governs these challenges, the field of Sustainable Development Goals (SDGs) deserves attention, and Education 5.0 is a key pillar. The primary challenge in this framework is to achieve sustainable collaboration among human competencies, machines, and technologies (Aheleroff et al., 2022), something that should be tackled according to social factors such as training, experiences, cognition, talents, human-machine interactions, and ethics, not just limited to smart technology (Neumann et al., 2021). With this framework, the relationship between SDGs, technologies, and human-centeredness has been illustrated even as a concept for a superintelligent society (Narvaez et al., 2021). However, to fit this concept, it is essential to identify the current and future demands of Society 5.0 and the challenges that technological education is facing.

To truly create a significant impact on the future of education, a more human-centered and creative environment must be designed. Enhancing connectivity and data ethics, reflecting SDGs as a blueprint for prosperity helped by lifelong learning, transdisciplinary education, human-centric design modules, and human-computer interaction experiences is the key to this purpose (Gürdür et al., 2022). Trending technologies such as virtual reality (VR) have been positioned as one of the best methods to enhance human-virtual interaction, with this technology being a potential force to improve sustainable education (Zholaushievna et al., 2022). Games have been shown to significantly enhance student motivation and learning effectiveness, offering crucial insights for institutions to revitalize curriculum designs and teaching (Lau et al., 2023). The list of opinions about some of the most influential technologies in education may go on and on, but their role in the achievement of SDGs and in the sustainability of education is not clear yet; therefore, this work aims to describe this relationship with the originality that it discusses insights from the most recent

literature about the 5.0 technologies used by institutions to tackle SDGs, how the institutions and researchers identify the human component of Education 5.0, the urgent adaptations to curricula and pedagogies, and the challenges in the future of Education 5.0, promoting the development of the SDGs.

Education 5.0, conceived as an evolution that harmonizes technology, humanity, and sustainability, is positioned as a transformative axis in the current context. In this sense, it is crucial to understand how its principles align with the goals set by the Sustainable Development Goals (SDGs), particularly in promoting inclusive, equitable, and quality education (Caparrós, 2024). Through this systematic literature review, conceptual and practical developments linking Education 5.0 and sustainability are explored, identifying innovative approaches and emerging trends that align with the research questions outlined below. This analysis allows not only to map the state of the art, but also to establish critical areas for intervention and future research opportunities. The theoretical framework underpinning this study is presented below, addressing the main conceptual foundations and key perspectives on the intersection between education and sustainability.

Theoretical framework

Education 5.0

Education 5.0 presents itself as an emerging paradigm that integrates advanced technologies with a humanistic approach, prioritizing social and environmental well-being. Unlike 4.0 education, which focuses on preparing for a world dominated by artificial intelligence and automation, 5.0 education seeks a balance between technological innovation and ethical values (Hashim et al., 2024). This approach fosters the development of individuals who can actively contribute to sustainability, linking education to today's global challenges (Supriya et al., 2024). It also considers the learner as an agent of change whose learning should be oriented toward solving complex problems in diverse contexts (Adel, 2022). In this framework, Education 5.0 transcends the instrumental use of technology to reconfigure the relationships between humans, technology, and the planet.

Education 5.0 in the future of education and its importance on sustainability

High-quality education must intrinsically be accompanied by vision and sustainable purposes and attend the demanding sector of Society 5.0. The future of education depends firmly on addressing this vision into a basic question: What challenges and opportunities does Education 5.0 have toward achieving SDGs with a human-centered transition? This is a question that institutions and governments should address to guarantee sustainable education Education for sustainable development lens: a policy and practice review tool (UNESCO, 2010). The societal demands in this new 5.0 era require a more humanized teaching to cultivate values, invest in training and infrastructure, and prepare students with individual, societal, and professional-based values (Nikum, 2022). This is imperative given that some authors are starting to question if we are losing the "human touch," suggesting that today in industry and education, everything is smart, and therefore, future skills are needed to face this automatization (Bakkar & Kaul, 2023). Institutions must adopt a new role to address these concerns and establish a sustainable new role of education in the new world economy.

The future of a sustainable education lies in the integration of innovative technologies, which are adapted to human capabilities and offer a sense of prosperity. Innovative technologies are reaching institutions that can serve as channels to real-world industry and applications for students. (Wang et al., 2022). To have the blueprint for prosperity in the new world economy, education at the age of Industry 5.0 must adopt new roles by using technologies and methods to cause changes and influences in learning and teaching environments, such as data analytics, cloud computing, cyber security, high performance of CPUs, etc., (Gürdür et al., 2022). The fact of enhancing learning experiences emulating environments that were previously difficult to access emphasizes the capabilities these technologies have in fostering innovative cognitive interests among learners (Zholaushievna et al., 2022). In this sense, the blueprint is dictated by a sustainable education, and new approaches are expected to emerge to make Education 5.0 reachable to everyone.

The future of a sustainable education that enhances productivity, increases opportunities for content sharing, supports inclusive development, and incorporates experiences through 5.0 technologies is the desired landscape of Education 5.0. However, the articulation between these technologies with the achievement and awareness of sustainable development objectives to form

a green economy is another desirable landscape (Deroncele-Acosta et al., 2023). The paradigm of the new 5.0 era is, therefore, not just a super-smart society and industry but one that allows institutions to access experimental energy programs, implement plans to reduce consumption, to use clean energies, promote gender equality, etc., (Fuchs et al., 2023); a paradigm center in a humanistic society, quality of life, placing human beings at the center of innovation and technological transformation (Tavares et al., 2023). Once we have focused on a humanistic society, it is important not to forget that the future of education needs to look forward to key creative and technological competencies and that education is transitioning into new curricula and pedagogy to face this 5.0 era.

Method

Research design

A systematic literature review (SLR) was selected for this research, as it allows for processing, synthesizing, and interpreting the available research related to a specific topic (Kitchenham & Charters, 2007). In the case of this review, the objective was to unveil research on Education 5.0 exploring the possible relationship with the Sustainable Development Goals, specifically with sustainability, there were explored the technologies used, curricular or curriculum changes, and finally, the challenges of Education 5.0 and its relationship with the SDGs. The methodology was based on the recommendations established by Verner (2012) and Kitchenham et al. (2009), in which five phases are proposed to structure the method, which are: research question, search processes, inclusion and exclusion criteria, data selection and extraction, and data synthesis. In addition, the PRISMA diagram was used to provide the necessary rigor required for this type of study (Moher et al., 2009), as shown in Figure 1, which shows the process of identification, review, and selection of information through a clear and reproducible process.

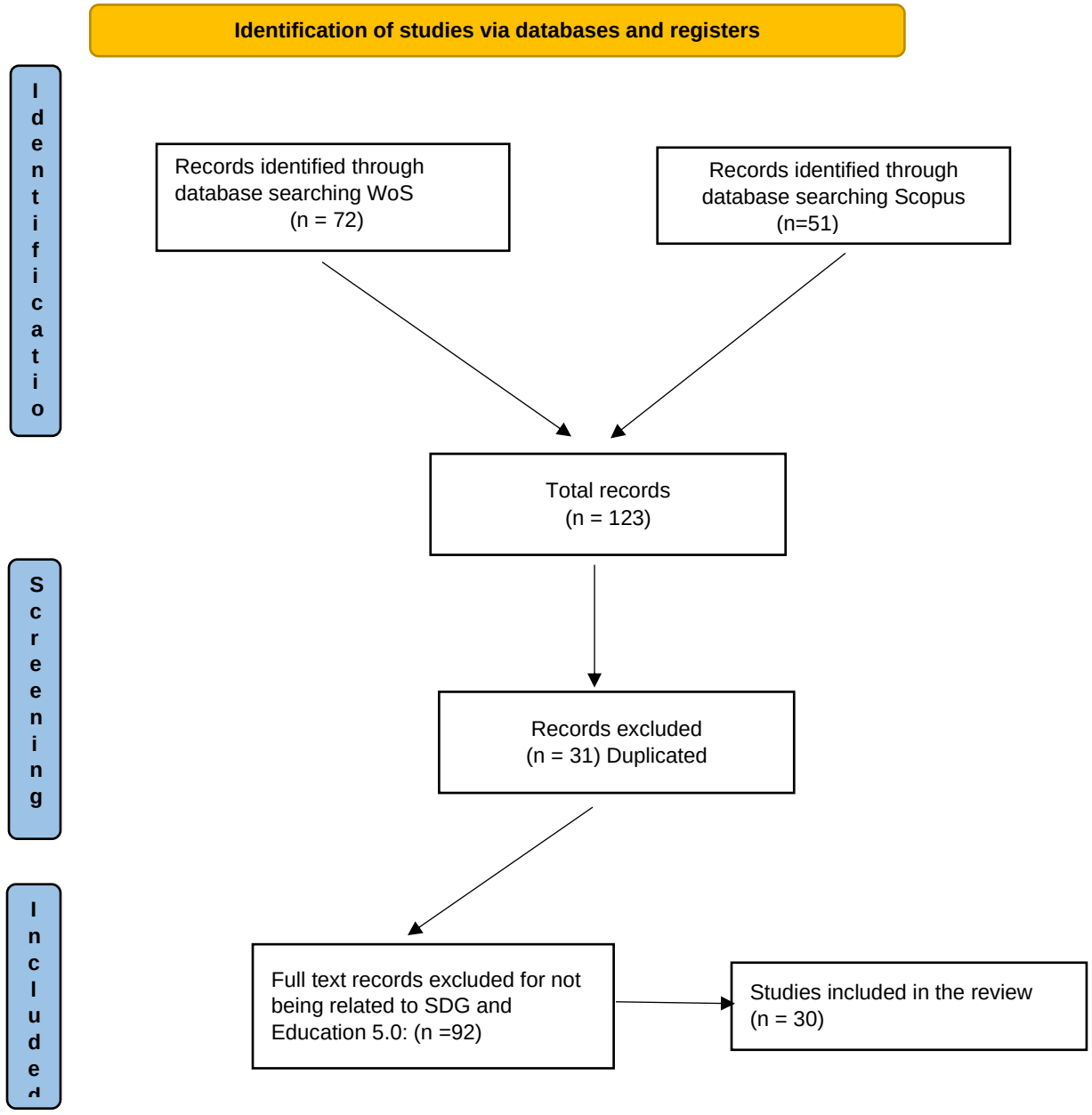

Figure 1. Review protocol based on PRISMA

Phase 1. Research questions: Taking into account the proposed objective of this review, which focused on unveiling the advances that have been made from Education 5.0 to address the Sustainable Development Goals, specifically sustainability, six research questions were proposed, which allowed characterizing the publications, examining the ways in which sustainability has been addressed from Education 5.0, and recognizing the possible challenges and challenges of Education 5.0, which can be seen in Table 1.

Table 1

Subjects and Research Questions

Subjects	Research Questions (RQ)	Responses
Characteristics of the publication that has integrated the topic of 5.0 technologies and its relationship with sustainability	Research Question1a: What are the most cited publications?	• The number of citations
	Research Question 1b: What are the journals with the higher citations / publications ratio?	• The journals with more Citescore
Sustainability approach	Research Question 2: What is the Sustainability approach?	• Sustainability on education (only SDG 04) • Achievement of any other SDG.
	Research Question 3: Which 5.0 technologies does the sustainable approach adopt?	• Digitalization and Tech 5.0 adoption • IoT sustainable adoption • AI sustainable adoption • BD sustainable adoption • CC sustainable adoption • Gamification sustainable adoption • Metaverse sustainable adoption
Curricula or Pedagogy	Research Question 4: Curricula or pedagogy changes? Were these changes incentivized by COVID-19 pandemic?	• Curricula • Pedagogy • Curricula incentivized by the pandemic
	Research Question 5: What are the main challenges in the future of Education 5.0 toward the SDGs?	• Widespread adoption of technologies • Intellectual property • Environmentally friendly projects • Index implementation • Resilience for sustainability • Interdisciplinary collaboration • Infrastructure deficiencies • Uncontrollable growth of technologies
	Research Question 6: Impact on sustainability for 5.0 technologies	• IoT impact on sustainability • AI impact on sustainability • BD impact on sustainability • CC impact on sustainability • Gamification impact on sustainability • Metaverse impact on sustainability

Phase 2. Search processes: It was defined that the search would be conducted in the Scopus and WoS databases taking into account their relevance and pertinence, in addition to their nature as

indexes of the sciences (Khalil et al., 2016). It was necessary to perform several exercises with various search strings that were composed of different terms and synonyms. When the term "Education 5.0" was included, very few results appeared (1 or 2); for that reason, it was necessary to perform a search equation that had some of the 5.0 technologies to broaden the search. Two different search equations were proposed but composed of the same terms, according to Table 2.

Table 2

Search equations

Scopus search equation	WOS search equation
(TITLE-ABS-KEY (iot OR "artificial intelligence" OR "cloud computing" OR "big data") AND TITLE-ABS-KEY (sustainability) AND TITLE-ABS-KEY (education)) AND PUBYEAR > 2014 AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (EXACTKEYWORD , "Education"))	education (Title) and sustainability (Title) and "artificial intelligence" (Title) and "cloud computing" (Title) and "big data" (Title) or IOT (Title) and Article (Document Types) and Article (Document Types) and Education Educational Research (Research Areas) and 2023 or 2022 or 2021 or 2020 or 2019 or 2018 or 2017 or 2016 or 2015 or 2014 or 2013 or 2011 or 2010 (Publication Years) and Article (Document Types) and English (Languages)

Phase 3. Inclusion and exclusion criteria: During the search process, the inclusion and exclusion criteria were applied to obtain limited and pertinent results that aligned with the objective pursued by the systematic literature review (SLR). In both equations, the results were limited to include articles in English published before 2024, and the journal categories were restricted to education, as shown in Table 3.

Table 3

Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Studies that are directly related to the SDGs and Education 5.0	Studies that will not address the SDGs and Education 5.0
Articles from scientific journals in the field of education	Review articles, conference papers, books, book chapters, reports, working papers, or articles not published or indexed in Scopus or WOS.
Articles published in English	Articles published in languages other than English.
Articles published before 2024	

Phase 4. Selection and data extraction: The final search was conducted on September 21, 2023, when the records were downloaded from both databases and the metadata were imported into

Mendeley. This process identified 31 duplicates, resulting in a sample of 92 articles that were selected and downloaded in full text.

Phase 5. Synthesis of data: To synthesize all the information, a matrix in Microsoft Excel was used, where the metadata was organized in columns and fields designated for this purpose. Additionally, each of the proposed research questions (RQs) was addressed in this section. At that time, when the articles were read in-depth, 62 articles that did not respond to the questions were discarded, leaving a definitive sample of 30 articles that contributed to the proposed research objective. The database is available at: https://doi.org/10.6084/m9.figshare.24540961.v1

Findings

This section presents the results for each of the research questions that were established and presented in the previous section. It begins with the questions related to bibliometric data that enrich and present the SLR.

Research Question 1a: What are the most cited publications?

The number of citations of each Journal in the period of 2019-2022 was searched and their percentage of citations was calculated. It was found that *Sustainable Development Journal* contributed the highest percentage of citations (20%) followed by *Cogent Business & Management* (15%). The percentage of citations of a Journal is a decision factor to account for when it comes to submit a particular topic in the trendiest journals, in our case, these Journals address the most cited articles regarding Education 5.0 and its impact in the context of sustainable development (Figure 2).

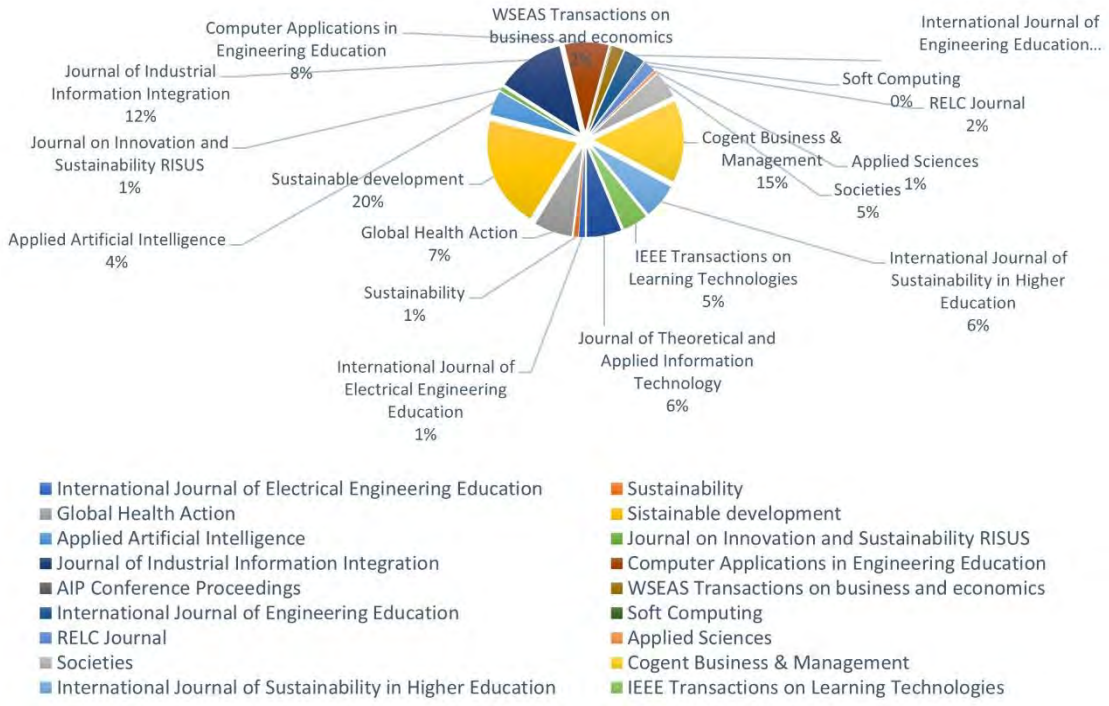

Figure 2. Percentage of citations of Journals referring to Sustainable Development Goals and Education 5.0.

Although the percentage of citations is an important decision factor, it is not the only neither the most important element to consider when choosing the most fitted Journal as there are some other metrics researchers should consider some as the Citescore and the SCImago Journal Rank (SJR) that will allow to have a broader weight vision of the prestige and citing historical of the journals.

Research Question 1b: What are the journals with the higher Publication /citations ratio?

Figure 3 shows the number of publications per journal and their citations, noting that Sustainable Development is the Journal with the most citations. The importance of this figure lies in showing the most trending journals for education and technology, with a focus on a particular topic of interest, as well as localizing the most cited journals with the highest number of documents released during the period of 2019-2022.

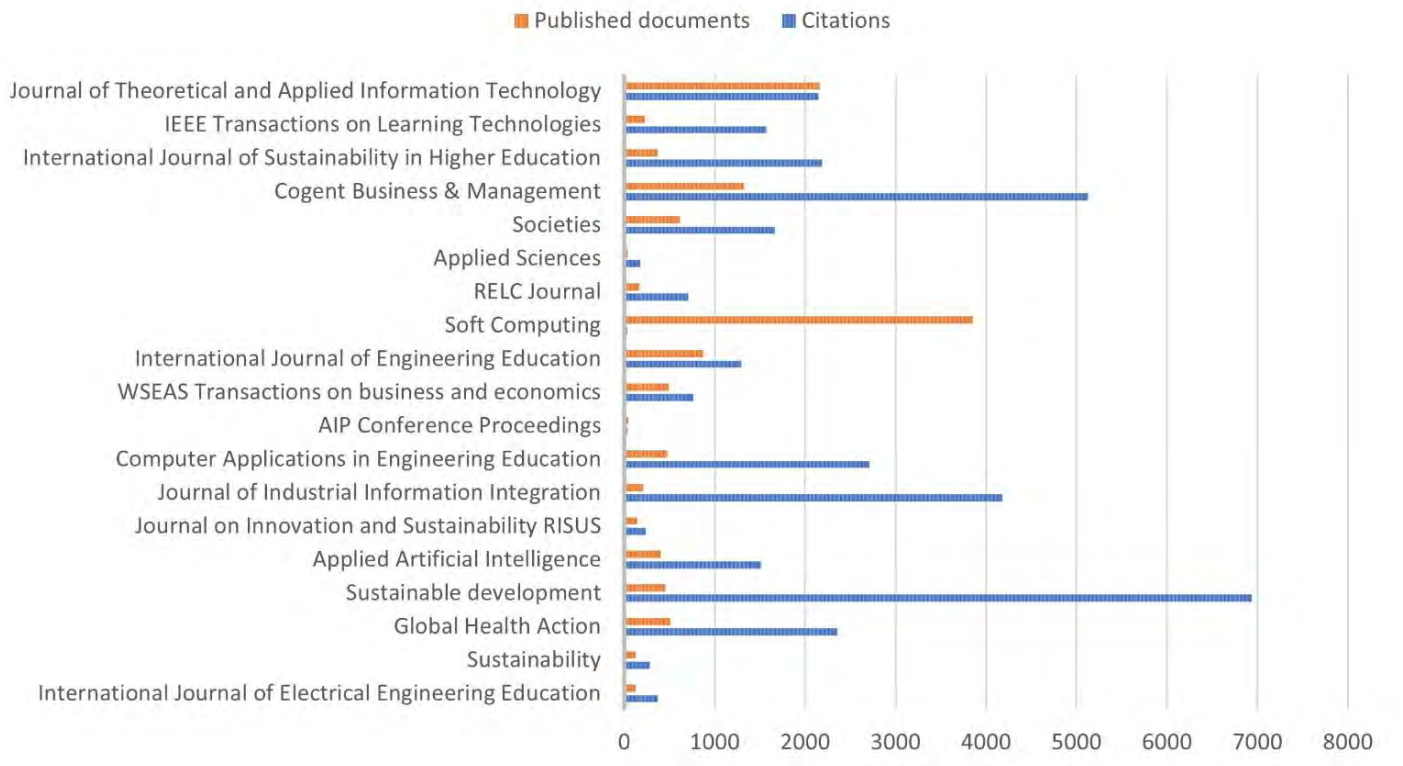

Figure 3. Number of publications and citations in Reviewed Journals in the period 2019-2022

The CiteScore metric is the representative ratio of average citations/documents published in a period, in this case published in a serial period of 4 years and in this case, although is not seen in the above bars, the calculated ratio (Citescore at 2022) for the three most trending Journals is: Sustainable development: 15.2; Journal of Industrial Information Integration: 19.6 and IEEE Transactions on Learning Technologies: 8.5. In this case, Cogent Business & Management has a 3.5 ratio which makes this Journal less relevant for citation success.

Research Question 2: What is the Sustainability approach?

As we mentioned in the search methodology, we investigated the number of 5.0 technologies that address the SDGs or the Sustainability of education. We identified that only when >2 technologies are addressed in the publications, their approach is in both directions: *sustainability in education* and *achievement of SDGs* (Figure 4).

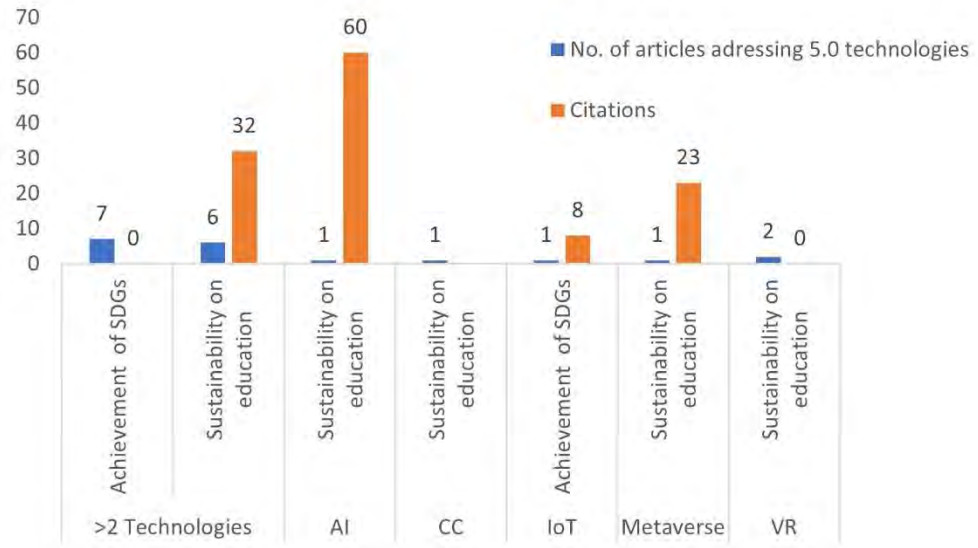

Figure 4. Number of publications addressing 5.0 technologies and citations in each approach.

The implications for Figure 4 for researchers are that it allows a rapid discrimination between the most cited topics based on two types of categories: the classification of sustainability and the classification of 5.0 technologies with its respective combinations, in this sense, they can take decisions to adequate its methodologies in terms of calculating the number of technologies and the sustainable scope they should address to have a higher impact in their investigations.

Research Question 3: Which 5.0 technologies the publications address?

Figure 4 also shows that the most cited technologies were AI, IoT, and the Metaverse, which are the trendiest and most widely adopted technologies in education, based on this classification. The lack of approaches for individual technologies toward sustainability is appreciated.

AI is the technology that has mostly influenced the researching processes given the easy accessibility and its multiple applications, however, as it can be appreciated, the approach of AI in Education 5.0 in combination with sustainability in education is still in progress and efforts to fill this gap should be accounted for in the new 5.0 era.

Research Question 4: Does the article approach curricula or pedagogy changes? Were these changes incentivized by COVID-19 pandemic?

It is important to notice that 11 publications proposed curricula or pedagogy changes in education and that 6 publications proposed changes that emerged during the COVID-19 pandemic which reflect the impact of 5.0 technologies and humanized environments to attend emergency scenarios accounting on SDGs, this sustainable approach under the concurrence of this 5.0 industrial revolution and pandemic is a matter of current interest. The articles with proposal changes on curricula or pedagogy in education based in 5.0 technologies and with directions toward SDGs were just a few of them: Kamarudin with proposal changes in curricula (teaching and learning) to implement a culture of digitalization and technologies 5.0 (Kamarudin et al., 2023); Liu et. al, with curricular changes for sustainable teaching physical education boosting digital technologies and big data with a focus in 5.0 Society (Liu, 2023); Meniado and cols., with a sustainable approach in digital language teaching (Meniado, 2023); Baglama et. al, with changes in digital leadership in school management using gamification (Baglama et al., 2022); Imran and colleagues with a proposal to assessed sustainability of online education using AI and students emotions (Imran et al., 2022). The landscape of 5.0 technologies under education and sustainability was also a focus of interest during the pandemic transition and based on this research, it was observed that 20% of the publications addressed this landscape.

Research Question 5: What are the main challenges in the future of Education 5.0 toward the SDGs identified in the literature? Table 4 summarizes the main challenges in the literature. As it is shown, most of the publications are addressing the widespread adoption of technology challenges.

Table 4

Challenges identified in the future of Education 5.0

RQ5 -Challenges	**Author**
Widespread adoption of technologies	(Alharbi, 2020), (Al-Ramahi et al., 2022), (Edwards & Cheok, 2018), (Han et al., 2023), (Liu, 2023), (Wang et al., 2022), (Zholaushievna et al., 2022), (Baglama et al., 2022), (Deroncele-Acosta et al., 2023), (Gollapalli et al., 2023), (Jääskä et al., 2021), (Imran et al., 2022), (Lee & Hwang, 2022), (Liliana et al., 2021), (Matas-Terrón et al., 2020), (Zeeshan et al., 2022).
Intellectual property	(Amorós et al., 2023)
Environmentally friendly projects	(Baig & Yadegaridehkordi, 2023)

Index implementation	(Guevara et al., 2020), (Fuchs et al., 2023)
Resilience for sustainability	(Gürdür et al., 2022)
Interdisciplinary collaboration	(Kamarudin et al., 2023)
Infrastructure deficiencies	(Kraus et al., 2023)
Uncontrollable growth of technologies	(Lantada, 2020)
Specialization needed for teachers	(Meniado, 2023), (Tavares et al., 2023), (Deroncele-Acosta et al., 2023)
Security and privacy concerns	(Tavares et al., 2023)
Funding	(Togo & Gandidzanwa, 2021)

The fact that describing the main challenges in the future of education offers the possibility to create awareness and prepare educators, students, and governments. Noting that widespread adoption is the common denominator in the literature, it represents a call for the former participants to identify the causes and then improve their strategies and methods to enhance adoptions without falling in foreseeable obstacles.

Research Question 6: What are the impacts on sustainability for 5.0 technologies? Table 5 summarizes the main impacts on sustainability for 5.0 technologies identified in the literature. The impacts are aligned to sustainability on education and tackling SDGs. It was found that just a few articles discussed the human-centeredness concept and the lack of strategies for its inclusion in decision-making under the six technological components analyzed in the investigation.

Table 5

Impact on sustainability for 5.0 technologies

Technology	Impact on Sustainability
IoT	- Promotes quality education for sustainable development (Zeeshan et al., 2022). - Facilitates intelligent resource management (Liliana et al., 2021). - Supports the sustainability of 2030 agenda through engineering education (Alharbi, 2020).
Cloud Computing	- Reduces costs by minimizing the need for expensive hardware and software. - Enhances disaster recovery, scalability, and knowledge sharing (Al-Ramahi et al., 2022).
Big Data	- Supports inclusive social development and measures knowledge, opinions, and emotions (Matas-Terrón et al., 2020).
AI	- Predicts assessments and areas of improvement (Gollapalli et al., 2023). - Refines teaching methods and enhances student satisfaction (Imran et al., 2022).
Gamification	- Increases curiosity and awareness of sustainability issues (Han et al., 2023). - Optimizes student knowledge in sustainability management (Jääskä et al., 2021).
Metaverse	- Enhances technological capabilities such as critical thinking and collaboration (Lee & Hwang, 2022). - Promotes sustainable learning by connecting students virtually (Lee & Hwang, 2022).

Evidently, the identification of impacts of these 5.0 technologies towards sustainability on education or SDGs allow the identification of advantages, limitations and some clues for taking decisions makers, institutions, researchers and students so that the future impacts of their investigations in the field of Education 5.0 reach new frontiers in capabilities, knowledge, inclusive social developments and competences that at the same time allow to add more value to sustainability and management; in this sense, they can enhance their preparedness to meet the 5.0 educational and technological expectations and their works can be always problem-solving oriented.

Discussion, Conclusion and Implications

In this section, as in the results, the discussion for each of the proposed Research Question is presented. Research Question 1a: The publications addressing special themes such as Education 5.0 and its applications toward the sustainability of education and SDGs represent an urgent need to escalate these trending investigations to different policies and programs. When the number of Journals aware of the Education 5.0 and sustainability is analyzed (**Figure 2**) it is noted that the journal with more publications is Sustainable Development. Other journals attending these central topics have not necessarily in its names these topics (e.g.: Cogent Business & Management with 15.0% of publications). A documentary review from Perú, identified that the main specific lines of research in education and SDGs are quality educational management, teaching learning evaluation, and educational innovation in digital technologies (Deroncele-Acosta et al., 2023); at least, based in an epistemological classification, management of education and its relationship with industry appear to be the favorite topics for those meant to publish about SDGs, quality of education and innovative technologies. The definition of Carayannis and Morawska: "In industry 5.0, humans beings and machines interact positively to achieve a more sustainable world" and their conceptions in which Education 5.0 acts in conjunction with science and the business sector (Carayannis & Morawska, 2023) help us to explain the match of Education 5.0 with Management and Industry. Education 5.0 is now been seen as the cornerstone for the sustainable development of countries that allows the combination between technologies, leadership and managerial strategies (Maddikunta et al., 2022). These conceptions help us to understand that sustainability is the implicit output when the human factors are added to the equation of education, industry, research, and management.

Research Question 1b: The interest in research about Education 5.0 with its human centeredness scope is a difficult task to track given the new of these concepts. The landscape is different when the number of citations per document is observed (**Figure 3**), in this regard, the higher Citescore (no. citations / no. publications ratio) is for the Journal of Industrial Information Integration. Publications on this journal have more probabilities for citations (Citescore of 19.6 vs 15.2 of Sustainable Development). Cogent Business & Management has numerous publications, but its impact is lower, as its Citescore is 3.5 (Citescores are not displayed in the Figure). This review found one publication for each of these three journals: Baig and Yadegaridehkordi discussed robot innovation, higher education sustainability, human-centric and ecosystems implementations, giving insights of future directions. (Baig & Yadegaridehkordi, 2023); Gürdür, addressed the digital transformation by strategies such as lifelong learning, human-centric modules, management courses and experiences based in human-machine interactions (Gürdür et al., 2022); and Tavares that identifies the urgent need for creating synergies to promote a sustainable society 5.0 and see educational institutions as the drive to this constantly changing process (Tavares et al., 2023). The authors' opinions in these publications reflect the urgent need to implement directions and synergies of education and industry with a personal vision in their expertise areas (computer science, engineering, and accounting professions), bringing to the Table opportunities to find investigate new synergies always in the margins of human-centered ecosystems.

Research Question 2: Knowing the approaches toward tackling sustainability since the origin of the 5th industrial revolution from the corner of education is a desired vision to understand trends and weaknesses in sustainability. In this review, approaches of Education 5.0 toward sustainability were divided in two: technologies in Education 5.0 to improve the sustainability of education (SDG 4) or toward the achievement of SDGs. Unfortunately, the achievement of SDGs is the topic less addressed in the literature (**Figure 4)**. The reason is that technological advancements and its developments are moving so fast that humans are losing their ability to adjust the technological expansion with their own well-being (Leal et al., 2020) and universities and education programs are getting delayed in attending the SDGs in all its angles, such as programs, curricula, funding, capacity building and research investment to attend sustainability issues (Kioupi & Voulvoulis, 2019). Attending the vision of Tavares, universities must alight to the 2030 agenda in terms of SDGs in the transition to the 5th industrial revolution, fostering suitable environments between

business, societies, and educational systems in which human participation is restructured to the benefit of the productivity and efficiency (Tavares et al., 2022). This is a paradigm given the industrialized world, and the new generation of researchers that are more oriented to emotional intelligence, commitment and leadership will be the key toward success in this sustainable revolution.

Research Question 3: The sustainability interest inside education is a subject to attend with higher priority and the disruptive technologies constitute the key to achieve this purpose. We investigated the number of technologies addressed in Education 5.0, the **Figure 4** shows that the number of articles addressing the importance of ≥ 2 technologies in Education 5.0 are certainly blooming, but the focus is just for articles addressing sustainability on education (32 citations); the number of articles in the literature addressing the realization of SDGs with disruptive technologies but with a focus to Industry 5.0 and Society 5.0 may be getting relevance in the literature but they do not mention explicitly the Education 5.0 concept (Kasinathan et al., 2022); furthermore, the mapping between industry 5.0 and Education 5.0 at 2022 is just looking through few sustainable branches such as waste management (Andres et al., 2022). An extensive list of disruptive technologies such as pervasive cameras, streaming services, drones, 3D printings, etc., are getting some scenarios of sustainable development (Kasinathan et al., 2022); however, AI, IoT and metaverse (with the greatest number of citations), within our perspective, are the technologies that are reaching every aspect in our society, from schools to media and industry, but the inconvenient is that only few researchers are analyzing their implementation on Education 5.0 and sustainability. In summary, this underbalance in attending sustainability under the industry and Education 5.0, is explained partially by the unfamiliarity of the topic and it is imperative to bring more global attention for research and investment toward the achievement of SDGs.

Research Question 4: The implementation of standardized curricula and pedagogy based in 5.0 technologies require universal indexes to measure the real achievements of SDGs as a pre-requisite to a stable transition of an educational system that embrace an equilibrated participation of humans through their capacities such as complex reasoning and higher order cognitive skills. The Education 5.0 therefore, demands that curricula undergo significant evolutions. Some universities, researchers, and professors have begun to integrate 5.0 technologies in different disciplines.

Kamarudin proposed changes in curricula to implement a culture of digitalization and technologies 5.0 (Kamarudin et al., 2023); Liu, for sustainable teaching physical education boosting digital technologies and big data with a focus in 5.0 Society (Liu, 2023); Meniado, with a sustainable approach in digital language teaching (Meniado, 2023); Baglama et. al, with changes in digital leadership in school management using gamification (Baglama et al., 2022) and Imran and colleagues with a proposal to assessed sustainability of online education using AI and students emotions (Imran et al., 2022). The COVID-19 pandemic also imposed stronger unprecedented challenges for renovation in curricula and practices of universities: in this review at least 20% of the publications proposed changes in curricula during the COVID-19 pandemic. Researchers and specialists around the globe have identified factors to renovate curricula in higher education in the margin of Education 5.0 and should be prepared to face improvised humanitarian emergence to achieve a more sustainable educational system more oriented to creativity, human capabilities, and inclusiveness.

Research Question 5: Education 5.0 is coming with many challenges such as the widespread adoption of 5.0 technologies, intellectual property issues, the urgent actions of governments to standardized universal index implementation to measure the SGGs, security and privacy concerns, funding, etc. **Table 4** summarized the former situations, it is observed that most of the authors agreed that widespread adoption of technologies in Education 5.0 is the main challenge, a fact that will prevail if resource inequality is not urgently attended in the world. These challenges should be focalized including in the equation the resilience of humans through its participative role in the productivity, respecting the production limits of the planet and putting research and innovation as priorities (Kraus et al., 2023). Some collaborative approaches have emerged between policymakers, communities, and universities; these bodies should incorporate initiatives aligning their purposes to apply for funding to support their initiatives and to strengthen interdisciplinary research (Togo & Gandidzanwa, 2021). Ahmad and cols. mention that challenges should be attended between technology and humanistic values with the aim to provide learners with enriching and tailored experiences and introduce for this aim technologies such as AI, IoT, Cloud Computing, Big Data, Gamification and the Metaverse (Ahmad et al., 2022). Thinking about the future of education, the task of institutions to simulate real-life projects using 5.0 technologies for the future of students is maybe the best way to prepare students and new researchers with criteria

and early adoption of good practices to enterprise environments based in the culture of sustainability.

Research Question 6: The advent of Society 5.0 has brought multiple technological components that have been incorporated to education with the potential to revolutionize this sector, particularly in terms of creating a more humanized approach that prioritizes student-machine interactivity and develop interfaces for collaboration. The impact on sustainability for 5.0 technologies applications is observed in **Table 5**, where it is noted that IoT is impacting through creating personalized learning environments with applications that narrow the educational gap between developed and developing nations given the simple that can be the technology, helping in personalizing learning (Zeeshan et al., 2022). Cloud computing, offers avenues for storing and processing data remotely, enhancing educational efficiency by reducing costs associated with information and communication technologies (Al-Ramahi et al., 2022). Meanwhile, the rise of big data is useful to harness vast amounts of information related to student success, enrolment, and other facets of education (Kurkovsky, 2019). Machine learning in education focuses on using AI to enhance students' industry-related skills and to accelerate streamlining accreditation processes (Gollapalli et al., 2023). Gamification has also emerged as a strategy to enhance sustainability in education by making learning more engaging through interactive games, also enhancing student curiosity about sustainability concepts (Han et al., 2023). Lastly, the metaverse, a relatively newer 5.0 conception, represents a virtual-reality space where users can interact with computer-generated environments (Lee & Hwang, 2022). As it has been observed, most of the impacts are related to sustainability on education. Therefore, more efforts are needed to extrapolate Education 5.0 to the achievement of SDGs to safeguard the guarantees and resources of our world.

Conclusions

The evolution of Education 5.0 is marked by a conscious integration of sustainable development, the infusion of advanced technologies, and the need to address the challenges that this new industrial era brings to us. This review brings to the conclusion that educational management and its relationship with Industry 5.0 are the trendiest topics of the era. This observation helped to understand the current interest in technologies, leadership, and managerial strategies inside Education 5.0 under the frame of sustainability. Unfortunately, advancements in tackling SDGs

are progressing so rapidly that humans are losing their ability to remain sustainable. Today, with the emerging technologies and their applications in the sphere of education, underscores the necessity for institutions to implement a new standard in curricula and pedagogy. The implementation of disruptive curricula will allow institutions to be prepared for humanitarian emergencies and align to the future challenges in the landscape of Education 5.0, where the widespread adoption of technologies is the main concern. The adoption of the 5.0 technologies will contribute to sustainability by intelligent resource management using IoT, will reduce costs by minimizing expensive hardware and software supported by cloud computing, will support inclusive social development with big data, predict assessments and enhance student satisfactions with AI, increase engagement with gamification and promote critical thinking and collaboration with metaverse. The future of education is coming with unprecedented challenges and the progress is still reaching institutions with impacts surpassing expectations.

The implications of 5.0 technologies and sustainability in education practice introduce an array of technological expansions accentuated in a more human-centrical vision with a higher student-machine interactivity and adapted learning experiences that open the frontiers for further investigation in this landscape. In the present and future of research and education, it is imperative to trace specific research trajectories that are aligned with sustainable development, specifically in the field of commitment to SDGs. Given that publications of educational innovation for the achievement of SDG 04 are a trending topic of publication, it is essential a disruptive technological transformation and research as the main factor contributing to the advancement of the quality of Education 5.0, particularly by focusing on AI, IoT, and metaverse as the most disruptive technologies. The implications for these visions in investigation motivate researchers to integrate the human component as the main ingredient of their publications, adding value to their investigations. The direct role of universities to stimulate and provide real environments for educators and researchers to increase sustainable key competencies, such as creativity and human-centered thinking, will surely reduce the gap in the access to novel technologies and real-life projects demanded by Society 5.0.

Studies suggest that in the future, special attention should be anticipated for possible worst scenarios; for example, Education 5.0 with traditional curricula and training methods may be

incapable of facing the needed progress for technological advancements and, therefore, may collapse the preparation of students for the future. Investing in economic inequalities to reach 5.0 technologies is certainly the main factor involved in the lack of favorable research in the field of Education 5.0 and SDGs. The problem-solving-oriented approach of low-to-middle-income countries gives a special opportunity for the educational institutions and their political systems, to create guidelines for a sustainable integration of these technologies in the emerging fields of research and development environments.

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