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*Review*

# The Convergence of Intelligent Tutoring, Robotics, and IoT in Smart Education for the Transition from Industry 4.0 to 5.0

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**Abstract:** This review paper provides a comprehensive analysis of the automation of smart education in the context of Industry 5.0 from 78 papers, focusing on the integration of advanced technologies and the development of innovative, effective, and ethical educational solutions for the future workforce. As the world transitions into an era characterized by human–machine collaboration and rapidly evolving technologies, there is an urgent need to recognize the pivotal role of smart education in preparing individuals for the opportunities and challenges presented by the new industrial landscape. The paper examines key components of smart education, including intelligent tutoring systems, adaptive learning environments, learning analytics, and the application of the Internet of Things (IoT) in education. It also discusses the role of advanced technologies such as artificial intelligence (AI), machine learning (ML), robotics, and augmented and virtual reality (AR/VR) in shaping personalized and immersive learning experiences. The review highlights the importance of smart education in addressing the growing demand for upskilling and reskilling, fostering a culture of lifelong learning, and promoting adaptability, resilience, and self-improvement among learners. Furthermore, the paper delves into the challenges and ethical considerations associated with the implementation of smart education, addressing issues such as data privacy, the digital divide, teacher and student readiness, and the potential biases in AI-driven systems. Through a presentation of case studies and examples of successful smart education initiatives, the review aims to inspire educators, policymakers, and industry stakeholders to collaborate and innovate in the design and implementation of effective smart education solutions. Conclusively, the paper outlines emerging trends, future directions, and potential research opportunities in the field of smart education, emphasizing the importance of continuous improvement and the integration of new technologies to ensure that education remains relevant and effective in the context of Industry 5.0. By providing a holistic understanding of the key components, challenges, and potential solutions associated with smart education, this review paper seeks to contribute to the ongoing discourse surrounding the automation of smart education and its role in preparing the workforce for the future of work.

**Keywords:** smart education; Industry 5.0; artificial intelligence in education; ethical considerations in smart education; upskilling and lifelong learning



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## 1. Introduction

Industry 5.0, referred to as the "human-centric industry," represents a transformative paradigm in the evolution of industrial manufacturing and automation. Building on the foundations of its predecessors, Industry 4.0, Industry 5.0 places a renewed emphasis on the intrinsic value of human labor, creativity, and skills within the industrial ecosystem. This concept reimagines the relationship between humans and machines in manufacturing by advocating for a holistic, collaborative, and symbiotic approach [1]. In essence, Industry 5.0 seeks to combine the strengths of human workers, characterized by adaptability, problem-solving abilities, and emotional intelligence, with the precision and efficiency of automated systems and robotics. It recognizes the limitations of pure automation and artificial intelligence, particularly in complex decision-making, innovation, and contexts

requiring empathy and human judgment. Consequently, Industry 5.0 promotes the integration of workers into manufacturing processes alongside advanced technologies to enhance productivity, product quality, and overall competitiveness [2]. It envisions a future where humans and machines work together harmoniously, each contributing their own unique strengths and fostering a more agile, sustainable, and responsive industrial landscape. This shift is of paramount importance in the current era, as it responds to the ever-increasing need for customization, flexibility, and rapid adaptation in the face of dynamic market demands. In this manuscript, we explore the theoretical foundations, practical implications, and the potential impact of Industry 5.0 on various industrial sectors.

Industry 5.0, also known as the Fifth Industrial Revolution, represents a new phase in the evolution of industrial processes, characterized by a shift towards human–machine collaboration and the integration of advanced technologies across various sectors [3]. Klaus Schwab, the founder and executive president of WEF, introduced the concept of the Fourth Industrial Revolution, also known as Industry 4.0, which focused on automation, digitization, and the implementation of cyber-physical systems to optimize productivity and efficiency [4]. Figure 1 demonstrates the revolution of industry throughout the generations, from the first generation to the fifth generation.

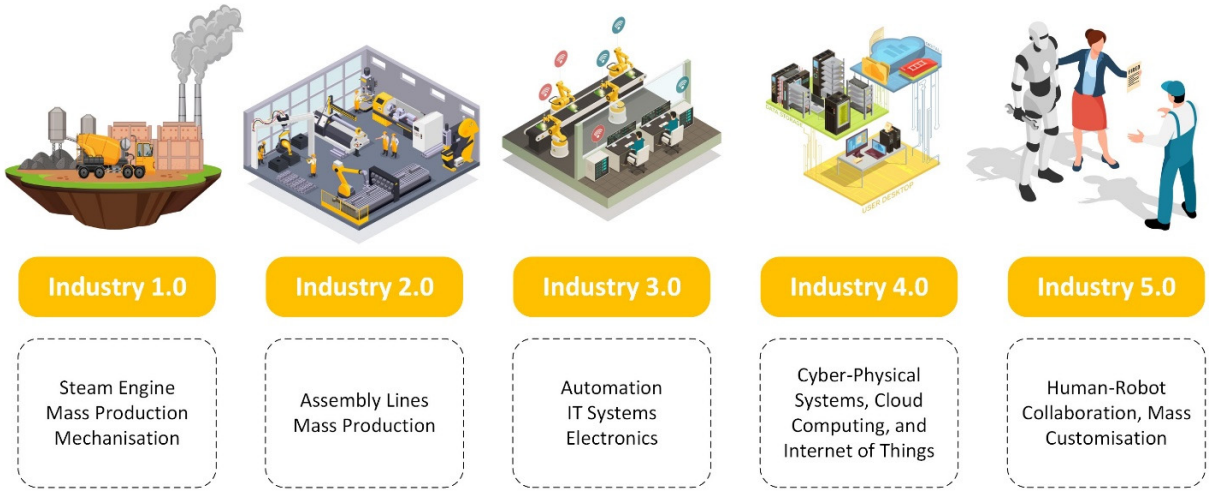


**Figure 1.** Industry Revolution.

The evolution of industrial revolutions can be summarized as follows:

(a) Industry 1.0: originating in the late 18th century, the First Industrial Revolution was marked by the transition from manual labor to mechanized production methods, driven by the invention of steam engines and the establishment of factories;
(b) Industry 2.0: emerging in the late 19th and early 20th centuries, the Second Industrial Revolution witnessed the advent of mass production and assembly lines, facilitated by the widespread use of electricity and the development of new materials and chemical processes;
(c) Industry 3.0: spanning the mid-20th century, the Third Industrial Revolution, also known as the digital revolution, introduced the use of computers, electronics, and automation in manufacturing processes, leading to enhanced efficiency and precision;
(d) Industry 4.0: beginning in the early 21st century, the Fourth Industrial Revolution emphasized the digitization of manufacturing and the adoption of cyber-physical systems, data analytics, and the Internet of Things (IoT) to create connected, responsive, and self-optimizing production systems;
(e) Industry 5.0: emerging in the 21st century, Industry 5.0 represents a progressive shift towards a human-centric approach in manufacturing. This revolution builds upon the foundations of Industry 4.0 but reimagines the role of humans in industrial processes. It promotes the integration of human workers alongside advanced technologies

to harness the unique qualities of human creativity, adaptability, problem-solving, and empathy. Industry 5.0 envisions a symbiotic relationship between humans and machines, fostering collaboration and co-creation to achieve greater productivity, quality, and flexibility in manufacturing. It acknowledges the limitations of full automation and AI in areas requiring complex decision-making, innovation, and human judgment. As a response to dynamic market demands, Industry 5.0 aims to create mass customization in a more agile, sustainable, and responsive industrial landscape by combining the strengths of both humans and machines.

### *1.1. Industry 4.0 and Industry 5.0–The Difference*

The concept of Industry 5.0, as discussed [5] differs notably from its predecessor, Industry 4.0. Firstly, it raises concerns about the nomenclature used for these industrial revolutions. The short time span between Industry 4.0's inception in 2011 and the emergence of Industry 5.0 prompts questions about the potential confusion and marketing-driven nature of labeling successive developments as new industrial revolutions. It also introduces the idea that a truly technology-driven revolution in fields like biological transformation or quantum technologies might warrant its own category, separate from the Fourth Industrial Revolution, with a focus on societal and ecological values.

Secondly, Industry 5.0 represents a shift from a technology-driven perspective to one centered around values. It argues that the purpose of technology should be to support human-centricity, ecological well-being, and social benefits rather than dictating societal change. This approach acknowledges the evolving nature of value creation, exchange, and distribution, particularly within the context of the fourth industrial revolution.

Moreover, Industry 5.0 emphasizes human-centricity and the role of technology in enhancing and supporting human capabilities, rather than replacing them. It strives for safer and more satisfying working environments, prioritizing the empowerment of workers. Industry 5.0 introduces a socio-centric perspective that extends beyond human-centricity. It aims to encompass broader societal and ecological values, recognizing the increased complexity of governance and responsible technology design required to achieve these goals. Lastly, Industry 5.0 does not seek to replace Industry 4.0 but rather to complement and extend its fundamental features. It represents an evolutionary continuation of the Fourth Industrial Revolution paradigm, incorporating a more comprehensive set of values, which transition from human-centric to socio-centric perspectives. This juxtaposition of values with technology signifies the maturation and evolution of the industrial revolution concept, addressing the dynamic societal changes driven by Industry 4.0 technologies.

Industry 5.0 builds on the advancements of Industry 4.0 by prioritizing the symbiotic relationship between humans and machines, aiming to combine the strengths of human intelligence, creativity, and empathy with the efficiency, accuracy, and speed of machines [6]. The main goal of Industry 5.0 is to create a more sustainable, innovative, and human-centric industrial landscape, addressing social, environmental, and economic challenges [7]. Industry 5.0 is fueled by an array of advanced technologies that are revolutionizing various sectors and transforming the way we work, live, and learn. These key technologies and their impact on education can be summarized as follows:

(a) Artificial intelligence (AI) and machine learning (ML): AI and ML enable machines to learn from data, recognize patterns, and make decisions with minimal human intervention [8]. In the context of education, AI-powered tools can assist in creating personalized learning experiences by analyzing individual learning styles, preferences, and progress [9]. Additionally, AI can facilitate the development of intelligent tutoring systems that can adapt to learners' needs and provide targeted feedback, enhancing the overall learning process, such as video games [10];

(b) Robotics: robotics technology involves the design, construction, and operation of robots that can perform tasks autonomously or semi-autonomously. In education, robots can be used for hands-on learning experiences, teaching programming and engineering concepts, and even assisting students with special needs [11]. Further-

more, collaborative robots or "cobots" can be employed in Industry 5.0 training environments, fostering effective human–robot interaction and teamwork;

(c) Augmented reality (AR) and virtual reality (VR): AR and VR technologies enable the creation of immersive and interactive digital environments. In education, AR/VR applications can be used to simulate real-world scenarios, providing learners with engaging and experiential learning opportunities [12]. This can be particularly useful in fields such as healthcare, engineering, and architecture, where students can practice their skills in a safe, risk-free environment before applying them in real-life situations;

(d) Internet of Things (IoT): IoT refers to the interconnection of physical devices, vehicles, buildings, and other items embedded with sensors, software, and network connectivity, allowing them to collect and exchange data. In education, IoT can be leveraged to create smart classrooms and campuses that offer enhanced learning experiences through the use of interconnected devices, real-time data analytics, and personalized content delivery;

(e) Advanced analytics: advanced analytics encompasses techniques such as predictive and prescriptive analytics, which use historical data to forecast future trends and make recommendations for optimal actions. In education, advanced analytics can be employed to identify patterns in students' performance, behavior, and engagement, enabling educators to make data-driven decisions that support student success and improve learning outcomes [13,14].

The integration of these technologies in education is leading to the emergence of smart education, which seeks to create adaptive, personalized, and immersive learning experiences that cater to the diverse needs of learners. The impact of these technologies on education is profound, necessitating the development of new pedagogical approaches, learning models, and curricula that align with the requirements of Industry 5.0.

As Industry 5.0 continues to reshape the global economy, the demand for skilled workers with proficiency in new technologies and interdisciplinary expertise is increasing [15]. Traditional jobs are evolving, and entirely new roles are emerging, making it essential for the workforce to adapt to these changes. Consequently, smart education plays a critical role in upskilling and reskilling the workforce to meet these demands and ensure that individuals can thrive in the new industrial landscape.

Upskilling refers to the process of providing individuals with the necessary training and education to enhance their existing skills and acquire new competencies relevant to their current roles. Reskilling, on the other hand, involves retraining individuals for new roles or industries in response to shifts in the job market caused by technological advancements or economic factors. Smart education supports workforce upskilling and reskilling in several ways.

### *1.2. Personalized Learning Experiences*

By leveraging AI and ML, smart education can provide tailored learning experiences that cater to individual learners' needs, preferences, and abilities [16]. This enables more effective skill development and knowledge acquisition, as learners can focus on areas where they need improvement or explore new topics at their own pace.

### *1.3. Adaptive Learning Environments*

Smart education systems can adapt to learners' progress, adjusting the difficulty of content and providing real-time feedback based on their performance. This helps ensure that learners receive the appropriate level of challenge and support, maximizing the effectiveness of the learning process [17].

### *1.4. Immersive Learning Experiences*

Through AR/VR technologies, smart education can offer engaging, experiential learning opportunities that facilitate the development of practical skills and competencies [18].

These immersive experiences enable learners to practice their skills in realistic, risk-free environments, promoting the transfer of knowledge to real-world situations.

### *1.5. Data-Driven Insights*

By harnessing advanced analytics and learning analytics, smart education systems can generate insights into learners' performance, engagement, and progress [19]. These insights enable educators, policymakers, and industry stakeholders to make informed decisions about curriculum design, resource allocation, and workforce development strategies.

### *1.6. Lifelong Learning*

Smart education promotes a culture of continuous learning and self-improvement, encouraging individuals to actively engage in upskilling and reskilling efforts throughout their careers [20]. This fosters adaptability, resilience, and a growth mindset, which are essential traits for success in the rapidly evolving landscape of Industry 5.0.

### *1.7. Research Gap and Contribution*

The research gap within the context of Industry 5.0 is a multifaceted challenge that encompasses technological, organizational, political, and societal dimensions. A notable research gap pertains to the complex interplay between these dimensions, especially in understanding and addressing the socio-centric and eco-centric values embedded within Industry 5.0. In this respect, Maddikunta and his co-authors in 2021 underscore the importance of exploring how Industry 5.0, which places an emphasis on societal and ecological well-being, can be practically implemented while ensuring the alignment of technology with human-centricity. The 2020 European Commission paper highlights the need to develop and implement policies that promote retraining and lifelong learning to address upcoming labor and skills shortages. It also calls for examining the societal heterogeneity to integrate diverse values and needs across various segments of the population, considering factors such as age, gender, cultural background, and diversity. Furthermore, the paper suggests that Industry 5.0 should move beyond the concept of corporate social responsibility (CSR) as a marketing tool and instead seek regulatory incentives to encourage companies, particularly SMEs, to embrace CSR as a core value, promoting societal and ecological well-being. Maddikunta and his co-authors also recognizes a critical research gap in addressing the interdisciplinary and systemic nature of Industry 5.0. It advocates for an interdisciplinary approach to research and design that involves engineering, technology, life sciences, environmental and social sciences, and the humanities. This interdisciplinary aspect is crucial in understanding the complex interactions between ecological, social, and economic factors within Industry 5.0. Additionally, the paper underscores the need for a systemic approach, which considers the interrelations at various scales of systems and the dynamic interactions among different industries and research disciplines.

The research gap in Industry 5.0 pertains to economic models that make ecological and social values approachable and financially sustainable. Mourtzis and other researchers emphasize the need for business models that align with ecological and social values and explore innovative mechanisms, such as digital platforms and ecosystems, to integrate multiple stakeholders. It also addresses the challenge of reconciling economic targets with ecological and social objectives to ensure that the economic dimension is not overlooked, leading to a holistic approach to economic, social, and environmental well-being.

Lastly, scalability represents a substantial research gap. The 2020 European Commission paper identifies that many Industry 4.0 technologies are yet to be fully implemented, particularly in SMEs and across entire value chains, and stresses the need for standardization and policy support for broader implementation. Achieving scalability necessitates a comprehensive understanding of entire industries and ecosystems, involving not only leading players but also SMEs, research organizations, universities, and legislative bodies. Research should focus on the systematic approach to scaling up new technologies and

fostering widespread adoption of Industry 5.0 across a broader spectrum of industry sectors and businesses, ultimately maximizing its impact on societal and ecological well-being.

### *1.8. The Scope and Objectives of the Paper*

The primary objective of this review paper is to provide a comprehensive analysis of the automation of smart education in the context of Industry 5.0. By examining the key components, technologies, and potential implications of smart education, we aim to inform educators, policymakers, and industry stakeholders about the critical role of smart education in preparing the workforce for the challenges and opportunities presented by the rapidly evolving industrial landscape.

The scope of the review paper includes the following topics:

(a) Key components of smart education: we will explore the essential elements of smart education, such as intelligent tutoring systems, adaptive learning environments, learning analytics, and the application of the Internet of Things (IoT) in education;
(b) Automation technologies in smart education: we will discuss the role of advanced technologies, such as artificial intelligence (AI), machine learning (ML), robotics, and augmented and virtual reality (AR/VR), in shaping personalized and immersive learning experiences;
(c) Integration of smart education within Industry 5.0: we will examine the incorporation of smart education in Industry 5.0, focusing on collaborative learning, human–robot interaction, competency-based education, skills assessment, and corporate partnerships;
(d) Challenges and ethical considerations: we will address the challenges and ethical concerns associated with the implementation of smart education, including data privacy, the digital divide, teacher and student readiness, and potential biases in AI-driven systems;
(e) Future directions and research opportunities: we will outline emerging trends, future directions, and potential research opportunities in the field of smart education, emphasizing the importance of continuous improvement and the integration of new technologies to ensure that education remains relevant and effective in the context of Industry 5.0.

### *1.9. Motivation of the Paper*

The motivation behind this article stems from the urgent need to understand the implications of Industry 5.0 on the global workforce and the education sector. As the world transitions into an era where human–machine collaboration and advanced technologies reshape the industrial landscape [21], it is essential to recognize the pivotal role of smart education in preparing individuals for the future of work. This article aims to contribute to the ongoing discourse surrounding smart education in the context of Industry 5.0 by providing a comprehensive analysis of its components, challenges, and potential solutions.

The key motivating factors for this article include:

(a) Rapid technological advancements: as AI, ML, robotics, AR/VR, IoT, and other advanced technologies continue to develop at an unprecedented pace, their impact on various industries becomes more significant. It is crucial to explore how these technologies are transforming education and how they can be leveraged to enhance learning experiences and better prepare individuals for the workforce of the future;
(b) Evolving workforce demands: the shift towards Industry 5.0 has led to the emergence of new roles and responsibilities that require a diverse range of skills and competencies. This article seeks to address the growing demand for upskilling and reskilling efforts, highlighting the importance of smart education in ensuring that the workforce is equipped with the necessary skills to thrive in the new industrial era;
(c) The need for lifelong learning: the dynamic nature of Industry 5.0 requires individuals to continuously update their knowledge and skills to remain relevant in the job market. This article emphasizes the role of smart education in fostering a culture of lifelong learning, promoting adaptability, resilience, and self-improvement among learners;

(d) Addressing challenges and ethical considerations: as the adoption of smart education increases, it is vital to acknowledge the potential challenges and ethical concerns associated with its implementation. This article seeks to address these issues, providing insights into possible solutions and best practices for creating equitable, accessible, and ethical smart education systems.
(e) Encouraging collaboration and innovation: by presenting case studies and examples of successful smart education initiatives, this article aims to inspire educators, policymakers, and industry stakeholders to collaborate and innovate, designing and implementing effective smart education solutions that meet the diverse needs of learners and align with the requirements of Industry 5.0;
(f) Identifying future research opportunities: this article serves as a foundation for further research in the field of smart education, outlining emerging trends, future directions, and potential research opportunities that can contribute to the ongoing development and improvement of education in the context of Industry 5.0.

The motivation for this article is to provide a comprehensive analysis of the automation of smart education in Industry 5.0, informing and inspiring stakeholders to embrace the transformative potential of advanced technologies and drive forward the development of innovative, effective, and ethical educational solutions for the future workforce.

## 2. Research Methodology Selection Criteria

The research methodology PRISMA was employed in this review paper and involves a systematic and comprehensive analysis of existing literature, case studies, and empirical data related to the automation of smart education in the context of Industry 5.0. The goal of this approach was to provide a holistic understanding of the key components, challenges, and potential solutions associated with smart education and its implementation in various sectors. The following steps outline the research methodology and selection criteria for the sources used in this review paper:

### *2.1. Literature Search*

A thorough search of scholarly databases, online repositories, and professional journals was conducted to identify relevant articles, books, reports, and conference proceedings addressing the topics of smart education, Industry 5.0, and their intersection. To ensure a comprehensive literature search for this review paper, a systematic search query was designed using relevant keywords and phrases related to smart education, Industry 5.0, and their intersection. To gather data for the review papers, an electronic search on various platforms, including Google Scholar, ACM Digital Library, ScienceDirect, IEEE Xplore, Scopus, and Springer were conducted. The following search query was utilized to gather sources for this review:

(a) (("smart education" OR "intelligent education" OR "adaptive learning" OR "intelligent tutoring systems") AND ("Industry 5.0" OR "fifth industrial revolution") AND ("AI" OR "artificial intelligence" OR "machine learning" OR "ML") AND ("workforce development" OR "upskilling" OR "reskilling"));
(b) (("human-machine collaboration" OR "advanced technologies in industry") AND ("learning analytics" OR "IoT in education" OR "Internet of Things in education") AND ("augmented reality" OR "AR" OR "virtual reality" OR "VR") AND ("lifelong learning" OR "continuous learning"));
(c) (("smart education" OR "intelligent education") AND ("Industry 5.0" OR "fifth industrial revolution") AND ("robotics" OR "automation") AND ("challenges" OR "ethical considerations" OR "data privacy" OR "digital divide"));
(d) (("smart education" OR "adaptive learning") AND ("Industry 5.0" OR "human-machine collaboration") AND ("best practices" OR "implementation" OR "case studies") AND ("educational transformation" OR "innovation"));
(e) (("intelligent tutoring systems" OR "learning analytics") AND ("Industry 5.0" OR "advanced technologies in industry") AND ("future research directions" OR "emerging

trends" OR "research opportunities") AND ("educational policy" OR "stakeholder collaboration")).

### 2.2. Selection Criteria

The identified sources were screened as shown in Figure 2 based on the following inclusion and exclusion criteria:

**(a) Inclusion criteria:**

i. Sources that discuss smart education and its components, including AI, ML, robotics, AR/VR, IoT, and advanced analytics;
ii. Sources that address the integration of smart education within Industry 4.0 and 5.0 to get more insights, with a focus on workforce development, upskilling, and reskilling;
iii. Sources that present case studies, examples, or best practices related to the successful implementation of smart education in various sectors;
iv. Sources that discuss the challenges and ethical considerations associated with the automation of smart education;
v. Sources that provide insights into future research directions and opportunities in the field of smart education.

**(b) Exclusion criteria:**

i. Sources that do not directly address the topics of smart education or Industry 4.0 or 5.0;
ii. Sources that are outdated or do not reflect the current state of knowledge in the field;
iii. Sources that lack empirical evidence or rigorous analysis.

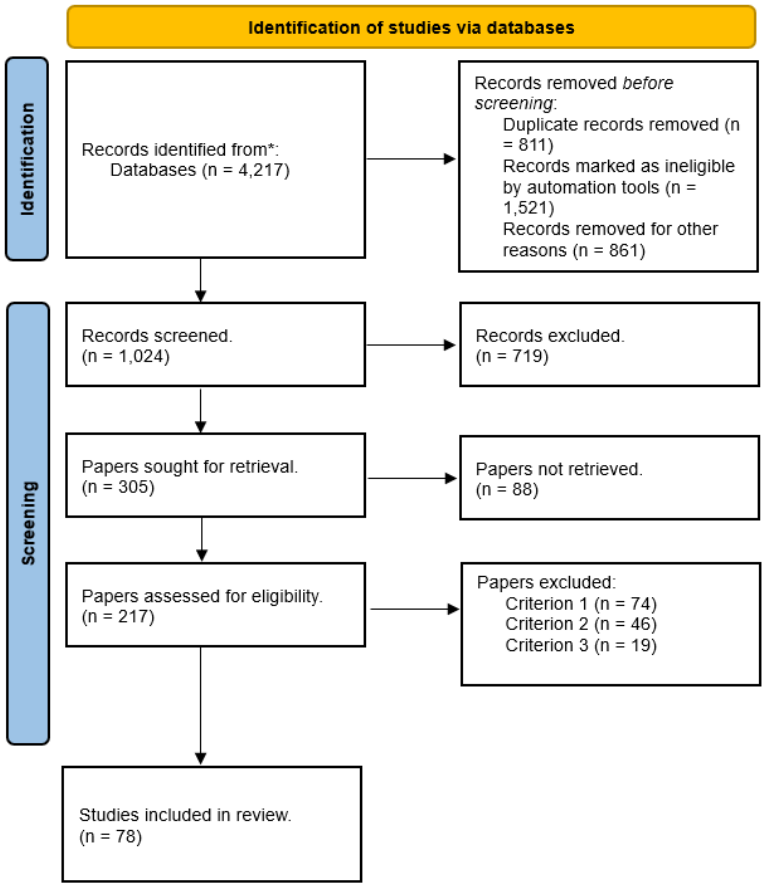


**Figure 2.** Selection criteria Process. * means all databases as a starting point.

### *2.3. Data Extraction*

Relevant information from the selected sources was extracted and organized according to the key topics and subtopics outlined in the review paper's scope. This process involved summarizing key findings, identifying common themes and trends, and noting any contradictions or gaps in the existing literature.

### *2.4. Synthesis and Analysis*

The extracted data was synthesized and analyzed to develop a comprehensive understanding of the automation of smart education in Industry 5.0. This involved comparing different perspectives, assessing the strengths and weaknesses of various approaches, and identifying opportunities for further research and development in the field.

### *2.5. Presentation of Findings*

The findings of the review paper are presented in a structured and coherent manner, following the proposed outline and addressing each topic in detail. The results are supported by evidence from the selected sources and are discussed in the context of their implications for educators, policymakers, and industry stakeholders.

By employing this research methodology and selection criteria, this review paper aims to provide a rigorous and comprehensive analysis of the automation of smart education in Industry 5.0, contributing to the ongoing discourse and informing future research and practice in the field.

### *2.6. Existing Survey Deficiencies*

While several surveys and review articles have been published in the areas of smart education, Industry 5.0, and the integration of advanced technologies in education, there are notable deficiencies in the existing literature that this review paper seeks to address:

Limited focus on the intersection of smart education and Industry 5.0: many existing surveys tend to focus either on smart education or Industry 5.0 in isolation without considering the synergies and interdependencies between the two. This review paper aims to provide a comprehensive analysis of the automation of smart education in the context of Industry 5.0, highlighting the importance of aligning educational efforts with the evolving needs of the workforce and the industrial landscape.

Insufficient discussion of challenges and ethical considerations: while some surveys mention the challenges and ethical concerns associated with the implementation of smart education, they often do not delve into these issues in depth. This review paper addresses this deficiency by providing a detailed analysis of the potential challenges and ethical concerns related to the automation of smart education, along with recommendations and best practices for mitigating these risks.

Lack of emphasis on collaborative learning and human–robot interaction: existing surveys often focus on the role of advanced technologies in enhancing individual learning experiences but do not adequately address the importance of collaborative learning and human–robot interaction in the context of Industry 5.0. This review paper seeks to fill this gap by exploring the role of collaborative learning and human–robot interaction in fostering teamwork, creativity, and problem-solving skills essential for the future workforce.

Narrow coverage of case studies and best practices: many existing surveys and review articles present only a few case studies or examples of successful smart education initiatives, limiting their ability to provide a comprehensive understanding of the various approaches, strategies, and contexts in which smart education can be effectively implemented. This review paper aims to address this deficiency by presenting a wider range of case studies and best practices from different sectors, regions, and educational settings.

Limited guidance on future research directions: while some surveys outline future research opportunities, they often do not provide a clear roadmap for researchers and practitioners interested in further exploring the field of smart education. This review paper seeks to address this gap by presenting a structured overview of emerging trends, future

directions, and potential research opportunities in the field of smart education and its integration within Industry 5.0.

**Ethical Considerations in the Automation of Smart Education**

Automation in smart education, while offering transformative potential, raises intricate ethical issues, particularly in relation to data usage, accessibility, and the long-term ramifications of students' digital footprints. A comprehensive exploration of these concerns is explained as follows:

1. **Data Usage and Privacy:**
   - **Purpose of Collection**: every piece of student data collected should have a clear, pedagogical purpose. Collecting data for the sake of it or for extraneous commercial purposes is ethically questionable;
   - **Informed Consent**: it is imperative that students (and parents, in the case of minors) understand what data are being collected, why, and how it will be used. They should have the option to opt-out without detriment to their learning;
   - **Data Security**: institutions must ensure that students' data are stored securely, protected from breaches, and not vulnerable to hacks or unauthorized access.
2. **Access and Equity:**
   - **Who Has Access?** beyond the educational institution, questions arise about third-party access. Will technology providers have access to student data? If so, for what purposes?
   - **Equitable Access**: there is the risk of creating or perpetuating inequities if only certain segments of the student population can access or benefit from smart educational tools due to socioeconomic, regional, or other barriers.
3. **Long-term Implications of Digital Footprints:**
   - **Data Retention**: how long is student data stored? Long-term retention poses risks, especially if the data becomes outdated or misrepresents a student's abilities and achievements in the future.
   - **Future Use**: will students' past performance, tracked and logged in detail, be used to predict or determine their future opportunities? For instance, could a student's learning history affect college admissions or job prospects?
   - **Right to Erasure**: students should have the right to request the deletion of their data after a certain period or upon completing their education. It is ethically sound to give individuals control over their digital histories.
4. **Transparency and Accountability:**
   - **Algorithmic Transparency**: with AI and ML playing pivotal roles in smart education, it is crucial to understand how these algorithms work. They should be transparent, and their decision-making processes should be explainable.
   - **Accountability**: institutions need to be accountable for any decisions made based on automated systems. If there is a mistake or bias in the system, there should be a clear mechanism for redress.
5. **Sociocultural Implications:**
   - **Cultural Bias**: automated systems, if not trained on diverse data, might exhibit biases. It is essential to ensure that these systems cater to a diverse student body and don't perpetuate cultural or socio-economic stereotypes.
   - **Holistic Development**: over-reliance on automation might ignore the holistic development of students, focusing solely on quantifiable metrics. Education should nurture not just academic but also emotional, social, and moral growth.

By addressing these deficiencies, this review paper aims to provide a more comprehensive and nuanced understanding of the automation of smart education in the context of Industry 5.0. Through the synthesis and analysis of existing literature and empirical evidence, this review paper seeks to inform and inspire educators, policymakers, and industry stakeholders to embrace the transformative potential of advanced technologies and drive

forward the development of innovative, effective, and ethical educational solutions for the future workforce.

## 3. Literature Review: Automation and Integration

To identify relevant papers for this study, a literature search was conducted using a combination of keywords related to the topic of interest. The initial search resulted in a limited number of papers that met the search criteria. In order to broaden the search and identify additional relevant papers, the Connected Papers tool was utilized.

Connected Papers is a web-based tool that visualizes connections between academic papers based on their citation relationships. To use this tool, the title of a relevant paper was entered into the search field. The resulting network graph displayed the paper's connections to other related papers, as shown in Figure 3, which allowed for an expanded search beyond the initial search criteria.

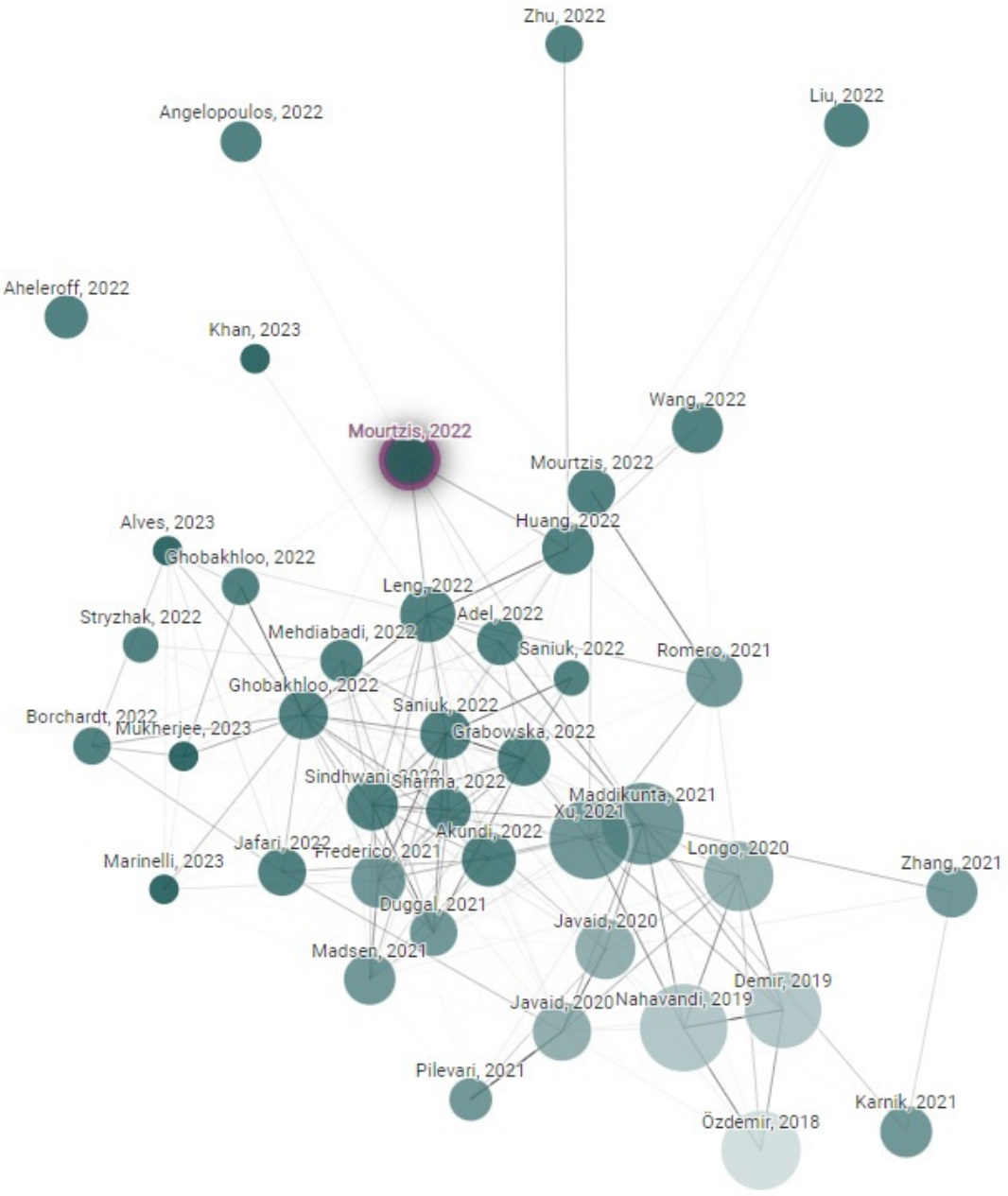


**Figure 3.** Connected Papers.

The network graph shown in Figure 3 was used to identify additional papers that were not captured by the initial search. By examining the connections between the papers, additional keywords and phrases were identified, which were then used to refine the search and identify additional relevant papers. This iterative process of searching and refining the search criteria using Connected Papers resulted in a comprehensive set of papers that met the search requirements.

The full findings obtained from the literature review are summarized in Appendix A, which outlines the key findings from each paper, including an abstract summary, main findings, and a question-relevant summary. This format allows for a clear and concise summary of the key findings from each paper, which can be easily compared and analyzed.

In addition to summarizing the key findings, this section includes critiques on the most recent, important papers with the highest focus on the integration between Industry 4.0–5.0 and smart education. This provides a balanced view of the literature and allows for a critical evaluation of the strengths and weaknesses of the existing research.

The literature review provides a comprehensive overview of the existing research on the topic and highlights the key findings that have been established in this section. By summarizing the findings in Appendix A, the key information of all studies is presented in a clear and concise manner, which makes it easy to analyze and compare. Additionally, the inclusion of possible critiques allows for a critical evaluation of the existing research, which can inform the development of the research question and study design.

*Literature Analysis*

The paper [22] demonstrates significant strengths related to smart education by focusing on the potential of Industry 5.0 technologies to address the challenges posed by the COVID-19 pandemic. It highlights the role of these technologies in providing personalized therapy, treatment, and remote monitoring in healthcare. The paper's emphasis on the real-time capabilities of Industry 5.0 aligns with the principles of smart education, as it illustrates the potential for innovative, technology-driven solutions in medical training and patient care. The paper's diagrammatic discussions of the supportive features of Industry 5.0 for the pandemic provide visual clarity and enhance the understanding of these technologies' applications. It recognizes the importance of personalization in fulfilling the specific demands of patients and doctors, making it a valuable resource for those in the healthcare and medical education fields during the ongoing pandemic.

The strength of this paper [23] lies in its recognition of the profound impact of the Fourth Industrial Revolution, or Industry 4.0, on the higher education system and, specifically, the training of future engineers for yet-to-exist professions. The analysis utilizes qualitative data from various sources and literature to identify key requirements for engineering education in this transformative context. It underscores the importance of nurturing soft skills for competitive professionals. The enumerated soft skills, including IT skills, information literacy, teamwork, flexibility, adaptability, learning, and cognitive skills, form a comprehensive framework for addressing the demands of the Fourth Industrial Revolution. By acknowledging the significance of these soft skills in the face of rapidly evolving technologies and interdisciplinary challenges, the paper provides valuable insights for shaping the education system to meet the needs of Industry 4.0, aligning well with the context of smart education. While providing valuable insights into the demands of the Fourth Industrial Revolution and the associated soft skills required, the paper does not explicitly mention connections to Industry 5.0. However, the development of soft skills highlighted in the paper can still be relevant in the context of Industry 5.0, where human-centric approaches and the integration of technology with societal issues are emphasized. The ability to adapt, collaborate, and think critically, as advocated in the paper, can remain valuable as industries continue to evolve into the human-centered paradigm of Industry 5.0.

The paper [24] presents a strong analysis of the potential synergy between Society 5.0 and Industry 5.0 and their implications for higher education. By emphasizing the need to place human beings at the center of innovation and integrating technology with

societal goals and sustainability, the paper aligns with the objectives of the United Nations Sustainable Development Goals, providing a strong basis for the argument. The discussion about the transformative role of universities in producing knowledge for new technologies and social innovation is well-supported. The paper's recommendations for universities to adopt new forms and channels of education, research, and innovation within the context of the Quintuple Helix Model (QHM) and Society 5.0 are practical and forward-thinking. This forward-looking approach aligns well with the evolving landscape of Industry 5.0, where the emphasis is on human-centered innovation and sustainability, making it a strong addition to the discourse on smart education in the context of Industry 5.0.

This paper [25] focuses on the transformative potential of Industry 4.0 in manufacturing, offering a comprehensive literature review of the concept and its implications. The paper's highlight is its effort to provide clarity in understanding Industry 4.0 by defining six design principles, including interoperability, virtualization, local real-time talent, service orientation, and modularity. The paper's in-depth analysis and systematic approach to reviewing the existing literature create a solid foundation for future research in the field. However, a critique of the paper lies in the lack of discussion about the practical challenges and limitations that may hinder the implementation of these principles. Additionally, while the paper addresses the impact of Industry 4.0 on manufacturing, it could delve deeper into its potential effects on society and education, which are briefly mentioned but not explored in detail.

The highlight of this paper [26] is its focus on the impact of Industry 4.0 on higher education, emphasizing the need to train qualified employees to prepare for the Fourth Industrial Revolution. The use of statistical data to underscore the importance of Industry 4.0 in education is a notable strength, as it provides empirical evidence for the claims made. However, a critique of the paper lies in the lack of depth and specificity in the literature. While it mentions the importance of Industry 4.0 in education, it does not comprehensively elaborate on the specific challenges and opportunities that higher education institutions may face. Additionally, it does not discuss potential solutions or strategies to address these challenges.

The paper [27] presents a comprehensive overview of the impact of Industry 4.0 and its associated technologies on companies' organization and technical capabilities. It correctly emphasizes the significance of the "digital shift" for maintaining competitiveness, and its recognition of the changes in competencies and skills required by employees and managers due to Industry 4.0 is noteworthy. The paper's focus on European initiatives supporting education within the Industry 4.0 context, especially the innovative didactic methodologies, is a strong point, as it highlights practical efforts to address evolving educational needs. However, a potential weakness lies in the need for the paper to provide more specific details about the innovative didactic methodologies, such as examples and their impact. Additionally, the paper could further explore the challenges and potential solutions related to the development of competencies and skills in the industry 4.0 era, providing a more holistic understanding of its implications for smart education.

The paper [28] offers a valuable perspective on the intersection of Industry 4.0 and Education 4.0, with a focus on higher education in Malaysia. Its strength lies in highlighting the awareness of the Malaysian government and its preparations to embrace Industry 4.0 and Education 4.0, which is crucial for staying aligned with global technological advancements. However, the paper is relatively brief and lacks specific details regarding the government's initiatives and strategies for this transition. To enhance the paper's impact, it could benefit from a deeper analysis of the challenges and opportunities that the Malaysian higher education system may face in adopting Industry 4.0 and Education 4.0. Additionally, providing more concrete examples of how these concepts are being implemented in the Malaysian context would strengthen the paper's contribution to the field of smart education.

The paper [29] provides a historical perspective on the evolution of education and its integration with technological advancements, including Industry 4.0. It effectively

highlights the keywords and concepts that have shaped education in the past two decades, placing them within the context of the internet phenomenon. The paper's strength lies in its ability to offer a broad overview of the connections between these concepts, presenting them as slogans of societal development. However, a critique of the paper is that it appears to be more of an introductory or retrospective piece, lacking an in-depth analysis of Industry 4.0's specific impact on education, particularly in the context of Slovakia. It raises important questions about the sustainability of future development but does not delve into potential solutions or strategies to address the issues it identifies.

The paper [30] presents a significant strength by addressing the transition from Industry 4.0 to Industry 5.0 and, subsequently, to Society 5.0. It emphasizes the shift from a machine-centric approach to a human-centric one in the context of technology, systems, and services. The paper highlights the importance of sustainability and human well-being in the next phase of industrial and societal development, which is essential for a balanced and equitable future. The critical literature review approach is a commendable method for providing a well-founded rationale for the transition to Industry 5.0. It offers valuable insights into the framework needed to facilitate this transition, which has implications for smart education as it implies a focus on human-centered, resilient, and sustainable design. Overall, the paper's strength lies in its forward-looking perspective on the coexistence of industry and societal needs in the era of Industry 5.0 and Society 5.0.

The paper [31] offers a compelling perspective on the strengths of Industry 4.0 and its implications for smart education. It emphasizes the creative changes in industry brought about by technological advancements and manufacturing systems, leading to the development of Industry 4.0. The paper correctly highlights the transformative potential of Industry 4.0 in optimizing resource utilization and addressing customer demands efficiently. It also underscores the role of wearable technology and embedded systems in handling large databases, which has implications for smart education, particularly in facilitating dynamic and personalized learning experiences. The paper's strength lies in its forward-thinking approach, stressing the importance of being technologically prepared to adapt to the changing educational landscape. It highlights the urgency for educational institutions to develop robust integrated systems and infrastructure that promote student-centered learning and lifelong learning. Overall, the paper provides a comprehensive perspective on the potential benefits of Industry 4.0 for smart education.

The paper [32] offers a notable strength in its focus on the identification of job roles in the context of transitioning to Industry 4.0. It acknowledges that the shift to this advanced production model is not an instantaneous process, primarily due to the significant financial investments required and the shortage of qualified personnel. By emphasizing the need to identify and define job roles, the paper addresses a critical aspect of Industry 4.0 implementation. It recognizes the importance of understanding the human resource requirements for successful adoption, which is essential for the long-term sustainability of Industry 4.0 in companies. This approach aligns with the broader concept of smart education, as it acknowledges the pivotal role of skilled employees in the industrial transformation driven by Industry 4.0.

The paper's strength [33] lies in its recognition of the significant impact of Industry 4.0 and the subsequent evolution towards Society 5.0, emphasizing the importance of both technology and human-centric considerations. It aptly identifies the transformation in various sectors driven by the utilization of cutting-edge technologies such as artificial intelligence, big data, robotics, automation, machine learning, and the Internet of Things. This perspective aligns with the principles of smart education, as it highlights the need for a holistic approach that integrates technological advancements with human well-being and societal development. The paper serves as a valuable introduction to the concept of Society 5.0 and its potential implications for smart education, paving the way for future discussions and research in this evolving field.

The paper [34] provides notable strengths related to smart education by recognizing the transformative impact of Industry 4.0 on the job market and the skills required by

employees. It highlights the need for a shift in teaching and educational techniques, emphasizing the importance of systemic and interdisciplinary thinking in education across various fields, not limited to technical areas. The paper's strength lies in its methodology, including a questionnaire survey conducted in Slovak companies, which allows for empirical data to support its conclusions. It effectively conveys the importance of adapting the content of education to align with the needs of Industry 4.0. The paper's emphasis on changes in workforce qualification structures contributing to increased company competitiveness and production effectiveness reflects a forward-thinking perspective that aligns with the principles of smart education. It proposes practical steps, such as vocational training and structural changes in the educational system, to address these evolving needs. Overall, the paper provides a valuable contribution to the discourse on smart education in the context of Industry 4.0.

The paper [35] demonstrates several strengths related to smart education, particularly in the context of Industry 4.0. It effectively positions Industry 4.0 as a transformative force in industrial markets, highlighting its connections to high-tech strategies, real-time data processing, and cyber-physical systems. The paper's focus on studying research articles in technical and vocational education and training (TVET) related to Industry 4.0 is commendable. By delving into these articles and incorporating recent findings, it provides a comprehensive overview of the field, serving as a valuable resource for future references. The paper's ultimate goal, which is to expose technical and vocational students to the latest technological innovations and prepare them for a more innovative workforce, aligns with the principles of smart education. Furthermore, it offers practical guidelines for policymakers to successfully integrate Industry 4.0 into TVET, emphasizing a proactive and forward-thinking approach to education in the era of Industry 4.0.

The paper [36] demonstrates a significant strength by highlighting the pervasive impacts of Industry 4.0 on various aspects of technology and workplaces. It recognizes that Industry 4.0 extends its effects into mobile applications, sensor-driven technologies, intelligent robots, and more. Moreover, it effectively anticipates the evolving demands of the job market in the future. The paper aligns with the principles of smart education by emphasizing the need for skills beyond technology-related ones, such as creativity, emotional intelligence, critical thinking, and interpersonal skills. Furthermore, it suggests that adapting to this changing landscape requires a whole new economic model and a departure from traditional systems. This forward-thinking perspective and recognition of the evolving nature of skills and education make the paper a valuable contribution to the discussion of smart education and its alignment with the emerging trends in Industry 5.0.

The paper [37] exhibits notable strengths in its exploration of the impacts of Industry 4.0 on education systems and its alignment with Education 4.0. It recognizes the transformative nature of Industry 4.0 on society and education, emphasizing the urgent need to develop new learning skills and abilities to empower individuals in the digital age. Through a literature review, the paper critically analyzes the potential of Industry 4.0 in the technology–education relationship, focusing on future skills and jobs. This forward-looking perspective aligns with the principles of smart education, and the paper serves as a valuable contribution to the ongoing discussion on the evolving landscape of education and its intersection with the emerging trends of Industry 5.0.

The paper's notable strengths [38] lie in its comprehensive examination of the significant changes brought about by Industry 5.0, which is characterized as a human-centered phase focusing on both economic development and enhancing the quality of life. It recognizes the profound impact of this transformation on the organization of education, aligning well with the principles of smart education. By emphasizing personalized education and the collective efforts of various stakeholder groups, including governments, educational institutions, industry, and students themselves, the paper underscores the importance of adapting the education system to meet the evolving needs of Industry 5.0. This forward-looking perspective positions education as a crucial component of societal change and

progress, making it a valuable contribution to the dialogue on smart education and its alignment with Industry 5.0.

The strength of this paper [39] lies in its synthesis of findings related to the digitalization of education in response to the challenges and opportunities presented by Industry 4.0. By focusing on the impact of Industry 4.0, characterized by big data and artificial intelligence developments, the paper highlights the skills needed in this era, including advanced analytics, the Internet of Things, and digital security. It underscores the broad-reaching effects of Industry 4.0 on both education and industry, emphasizing the need for swift adaptation to disruptive technologies. This analysis is particularly relevant in the context of smart education, as it underscores the importance of education's role in preparing a competent workforce to meet the demands of Industry 4.0. By addressing these challenges and opportunities, the paper contributes to the discourse on smart education and its alignment with Industry 4.0.

The paper [40] provides a strong analysis of the transition from Industry 4.0 to Industry 5.0 and its implications for education, particularly in the context of the COVID-19 crisis. It highlights the emergence of new mantras and values brought about by the pandemic, emphasizing wisdom, contentment, and human touch. The vision of Industry 5.0 leading toward Society 5.0 is well articulated, showcasing the role of educators 5.0 and smart collaborative robots in a super-smart society. The mention of the New Education Policy (NEP) 2020 in India and its alignment with Education 5.0 provides a practical example. The paper's focus on methodologies and techniques required for achieving the goals and objectives of Society 5.0 is a strong point, as it offers actionable insights into the future of education in the Industry 5.0 era.

The remaining studies, which encompass a comprehensive exploration of topics related to smart education and the transitions from Industry 4.0 to Industry 5.0, have been thoughtfully organized and presented in a structured manner for easy reference. For a detailed overview of these studies, readers are encouraged to refer to Appendix A, where a comprehensive table provides a concise summary of each study, including their key themes, strengths, and any connections to the Industry 4.0–5.0 framework. This tabulated format ensures that readers can efficiently access and navigate the wealth of information and insights encapsulated within the various studies, fostering a deeper understanding of the evolving landscape of education and industry in the digital age.

## 4. Discussion of Selected Studies

This section provides a detailed analysis and interpretation of the results obtained from the literature review. This section shows the distribution of the reviewed papers for the publications by year and publication numbers. This information provides an overview of the research activity in the field and can help to identify future trends and changes in research focus over time.

In addition to the distribution of papers, the most widely used keywords based on the studied articles are also analyzed. This analysis provides insights into the research topics that are currently of the most interest in the field. By identifying the most commonly used keywords, researchers can better understand the current research landscape and identify potential areas for future research.

The countries of publications where the most cited journals, conferences, or books were published are also considered. This analysis provides insights into the geographic distribution of research in the field and can help to identify regional differences in research focus and activity. Understanding the global distribution of research activity can be important for identifying potential research collaborators and for ensuring that research is relevant to diverse populations.

The discussion of selected studies provides a comprehensive analysis of the literature review findings and helps to contextualize the research trend within the current state of research in the field. By analyzing the distribution of papers, most widely used keywords,

and countries of publications, researchers can gain valuable insights that can inform the design and execution of the research study.

*Industry 5.0 and Smart Education Worldwide Research Productivity over Time*

The chart in Figure 4 displays the search interest for industry 5.0 and smart education over the last 5 years worldwide, with the numbers representing the interest level relative to the highest point on the chart. A score of 100 indicates the peak popularity for the term, while a score of 50 represents half the popularity. If the score is 0, it indicates that there was insufficient data available for the term.

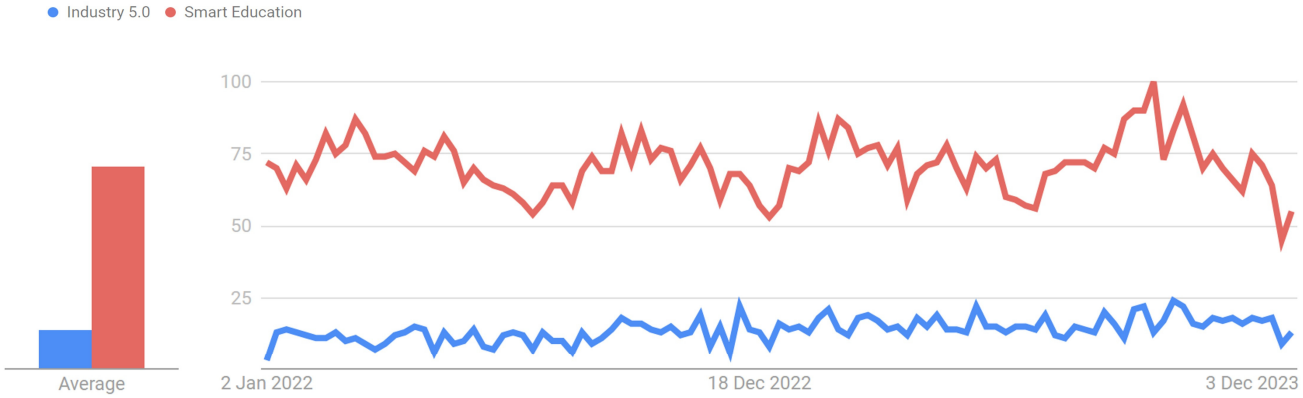


**Figure 4.** Research productivity over time.

Figure 5 represents a map that shows the breakdown of the terms "Industry 5.0" and "smart education" through a geo-map, which will be further elaborated in Figure 6. The map displays the popularity of these terms across different regions and countries, allowing for a comparison of the interest level in these terms across different parts of the world.

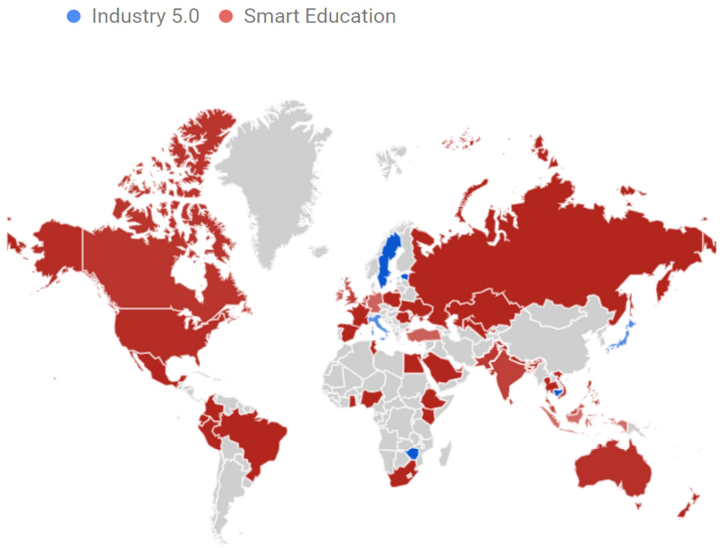


**Figure 5.** Geo-map of Industry 5.0 and smart education.

By analyzing the breakdown of these terms by region, we can gain insights into the regional differences in interest and focus on these topics. For example, we can identify which regions have the highest and lowest interest in Industry 5.0 or smart education, and we can compare the regional distribution of interest to identify any patterns or trends that may exist. This information can be useful for businesses, policymakers, and researchers who need to understand regional differences in the adoption of new technologies or approaches.

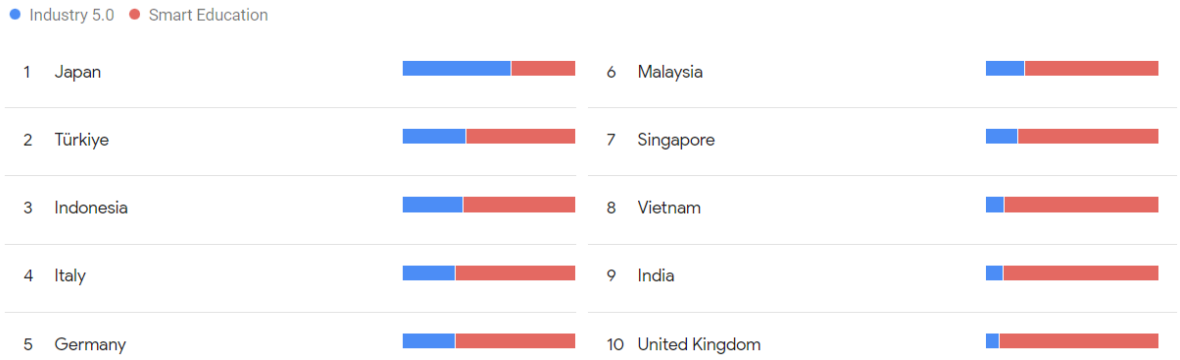


**Figure 6.** Top 10 countries of interest.

The top 10 countries of interest have been identified according to the search. Figure 6 clearly shows a higher interest in smart education with a lack of interest in Industry 5.0 due to the freshness of the generation and the need to identify all challenges to be tackled before fully migrating into the new industry generation.

This can be obviously seen in the following Figure 6, when the geo-maps of both interests have been separated to demonstrate the focus of research of Industry 5.0 is limited by certain countries.

Based on the map in Figure 7 that shows the comparison of research innovation in Industry 5.0 and smart education, it appears that there is more innovation applied in smart education compared to Industry 5.0. This could suggest that there is a greater interest and investment in research related to smart education compared to Industry 5.0.

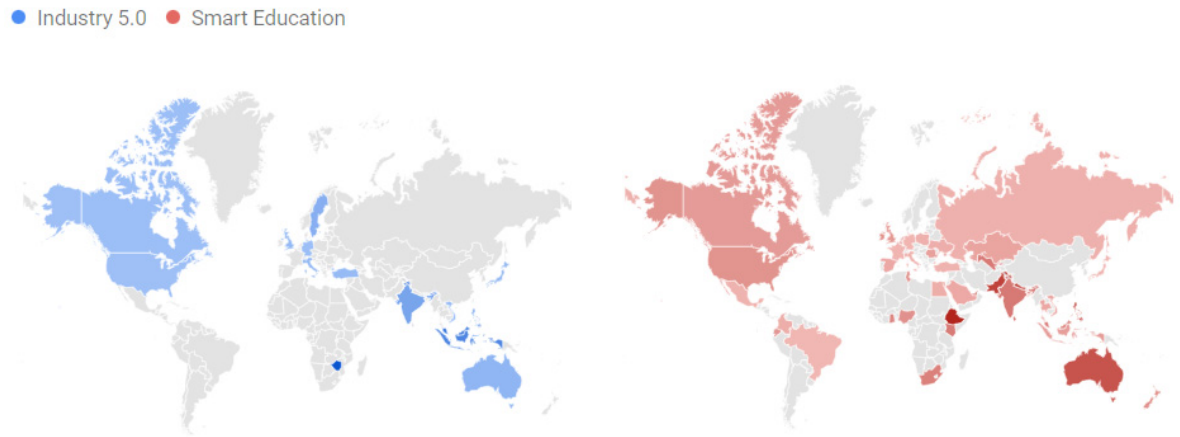


**Figure 7.** Comparison of research innovation in Industry 5.0 and smart education.

However, it is important to note that this map provides a broad overview and does not account for specific research activities or innovation initiatives in each country. It is possible that there are significant efforts underway in certain countries to advance research and innovation in Industry 5.0, even if the overall levels of innovation in this area are lower than those in smart education.

This map states that conducting research in Industry 5.0 is important as it can lead to significant advancements in manufacturing and production processes, as well as the development of new technologies and systems that can improve efficiency, productivity, and sustainability. These advancements can positively impact multiple sectors, specifically the education section, which has been severely affected by COVID-19.

Moreover, the innovations developed in Industry 5.0 can also have applications in smart education. For example, the use of advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), and robotics in Industry 5.0 can provide opportunities for the development of smart classrooms and learning environments. This can enhance

the learning experience and improve educational outcomes. Furthermore, the integration of Industry 5.0 technologies in the educational sector can also help prepare students for future careers in fields related to Industry 5.0.

In Figure 8, it is evident that users are searching for information on Industry 5.0 across various sectors, with the figure ranking these sectors based on their popularity. The rankings are based on a relative scale, where a score of 100 represents the most searched topic and a score of 50 represents a topic that is searched half as often as the most popular term, and so on.

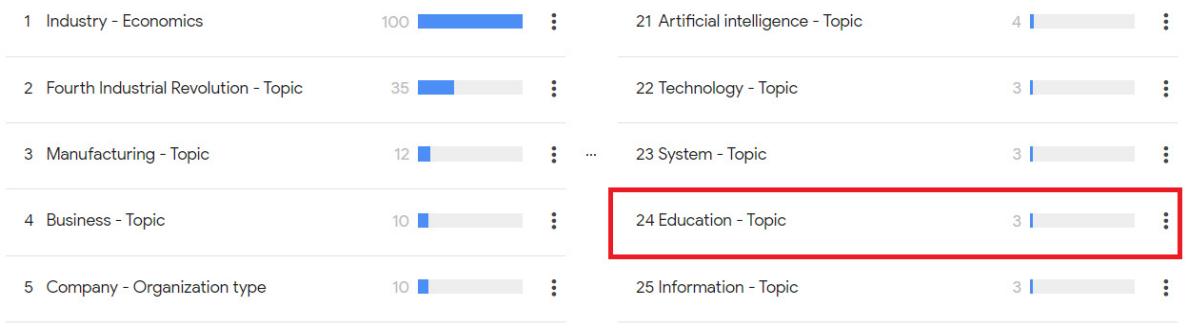


**Figure 8.** Topic's Popularity in Industry Generations 4.0–5.0.

The figure clearly indicates that the education sector is ranked 24th in terms of popularity, suggesting that there is relatively lower interest in researching Industry 5.0 in this area. This highlights the need for further research in exploring the potential of Industry 5.0 in education, which could lead to new and innovative solutions that improve the learning experience and educational outcomes.

Figure 9 demonstrates that there is a lack of knowledge and understanding of Industry 5.0 among the general population. This lack of knowledge can impact society as a whole by limiting the potential benefits that Industry 5.0 can provide, particularly in the education sector. By investing in research and education on Industry 5.0, we can increase awareness and understanding of this emerging technology and its potential applications, which could lead to significant advancements in various industries and ultimately improve the quality of life for people on many levels around the world.


**Figure 9.** Related Queries.

## 5. Challenges and Ethical Considerations

In the process of conducting an extensive analysis of 78 papers focused on smart education in the context of Industry 5.0, a range of challenges and ethical considerations emerged. These factors are crucial to address in order to ensure the effective and ethical implementation of smart education within Industry 5.0 while minimizing any adverse effects. By examining and tackling these challenges and ethical considerations, it becomes

possible to establish a learning environment that is equitable, effective, and nurturing for all learners.

Economic inequality and access: high costs associated with state-of-the-art AI hardware and software can lead to a concentration of AI capabilities within affluent organizations or countries. This limits the democratization of AI and the spread of its benefits. Ethical consideration: when only a select few have access to advanced AI tools due to economic constraints, it perpetuates inequalities. Smaller companies, researchers, and developing nations may be left behind in the AI race.

Data privacy is a primary concern as the integration of advanced technologies within education often involves the collection, storage, and analysis of vast amounts of personal information about students. Protecting this data from unauthorized access, breaches, and misuse is essential to maintain trust among students, parents, and educators. Developing robust privacy policies, secure data storage and transmission solutions, and transparency in data handling practices are necessary steps toward ensuring data privacy in the context of smart education.

The digital divide represents the disparity in access to technology and digital resources between various socioeconomic, geographic, and demographic groups. Implementing smart education without addressing the digital divide risks exacerbating existing inequalities and leaving disadvantaged students behind. Strategies to bridge the digital divide include providing affordable access to technology, ensuring reliable internet connectivity, and developing digital literacy programs for students, teachers, and communities. Students from affluent backgrounds are more likely to have access to advanced devices, high-speed internet, and other tools essential for smart education. Conversely, those from poor backgrounds might lack even basic digital resources, putting them at a disadvantage. While urban centers tend to be equipped with better infrastructure and resources conducive to smart education, rural areas, especially in developing countries, may lack essential connectivity and technological facilities.

Teacher and student readiness is another critical challenge, as the successful integration of Industry 5.0 technologies in education relies on the ability of educators and learners to adapt and utilize these tools effectively. Developing comprehensive training and support programs for teachers, as well as fostering a growth mindset among students, can help to ensure that both groups are well-equipped to navigate the rapidly changing educational landscape.

Biases in AI-driven systems can lead to unfair or discriminatory outcomes in the educational context. Ensuring the algorithms that underpin these systems are transparent, unbiased, and regularly audited can help minimize the risk of perpetuating harmful stereotypes or reinforcing existing inequalities. Additionally, fostering diversity and inclusivity in the design and development of AI-driven educational tools can help to address potential biases.

Ethical considerations around AI involve assessing the implications of using AI in educational settings, including its impact on student autonomy, surveillance concerns, and the potential to manipulate or influence learner behavior. To address these ethical considerations, it is vital to develop guidelines and policies that ensure the responsible use of AI in education, emphasizing transparency, accountability, and respect for individual rights and values.

Technological limitations, such as the accuracy, reliability, and scalability of AI, IoT, and other Industry 5.0 technologies, can impact their effectiveness and applicability in the educational context. Continued research and development, as well as collaboration between academia, industry, and policymakers, can help to overcome these limitations and ensure the successful deployment of advanced technologies in education.

Finally, social and cultural context plays a vital role in determining the success of smart education in Industry 5.0. Recognizing the diverse needs, values, and expectations of different communities and cultures is essential to ensure that the implementation of advanced technologies in education is sensitive, inclusive, and relevant to the local

context. This involves engaging stakeholders, promoting cultural awareness, and incorporating local knowledge and perspectives into the design and implementation of smart education initiatives.

Figure 10 demonstrates the seven challenges and ethical considerations of smart education in Industry 5.0 explained in this section and summarized as follows:

- Economic inequality and access: high costs of AI hardware and software can concentrate AI capabilities among the affluent, limiting broader access and exacerbating economic inequalities;
- Data privacy: the use of digital technologies in education can result in the collection and storage of sensitive student data, and there is a need to protect this data to ensure it is not misused or accessed by unauthorized parties;
- Digital divide: the unequal access to technology and digital resources among different groups of people is a significant concern. Smart education in Industry 5.0 must ensure that all students have access to the necessary technology and resources to participate fully in the learning experience;
- Digital support: many educators may not be familiar with the latest technologies and may require additional training and support to effectively incorporate them into their teaching practices. Similarly, students may require guidance and support to effectively navigate the new learning environment;
- Biases in AI-driven systems: AI systems in education can perpetuate existing inequalities or stereotypes. It is essential to design and implement AI systems in a way that is fair and unbiased and does not reinforce harmful or discriminatory practices;
- AI ethics: there are concerns around the use of AI in education, particularly regarding issues of accountability, transparency, and bias. These concerns must be addressed to ensure that the use of AI in education is ethical and beneficial for students;
- Technological limitations: smart education in Industry 5.0 relies heavily on technology, and any limitations or disruptions in the technology can affect the quality of education;
- Social and cultural context: smart education in Industry 5.0 must be developed with consideration of the social and cultural context of the students. It is essential to avoid any cultural insensitivity or stereotypes in the development and implementation of the smart education system.

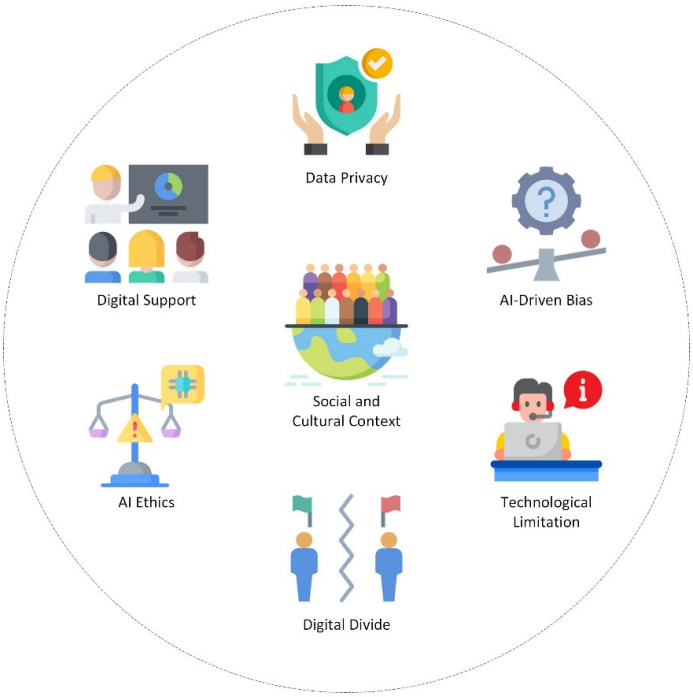


**Figure 10.** Challenges and ethical considerations.

## 6. Future Directions of Research

This section presents a comprehensive overview of multiple critical future research directions that aim to both comprehend and harness the potential of Industry 5.0 technologies to revolutionize the educational landscape according to the challenges and limitations presented in the current literature. These research directions encompass a wide range of topics, from exploring innovative ways to integrate advanced technologies into the education sector to examining their impact on teaching, learning, and ethical considerations.

By focusing on understanding the transformative power of Industry 5.0 technologies, researchers can gain valuable insights into the ways these technologies can augment traditional educational methods, improve learning experiences, and address existing challenges. This knowledge is essential for educators and policymakers to make informed decisions when implementing these technologies in various educational contexts.

Leveraging the transformative power of Industry 5.0 technologies involves not only understanding their capabilities but also actively applying them in innovative ways to improve educational outcomes. By exploring new techniques, tools, and approaches, researchers can identify best practices and strategies for utilizing these technologies to their fullest potential, ultimately shaping the future of education.

The outlined research directions underscore the need for a multi-faceted approach, incorporating a diverse array of subjects, such as personalization, critical thinking development, teacher training, and ethical considerations. This comprehensive perspective ensures that the application of Industry 5.0 technologies in education is not only effective but also equitable and responsible.

### *6.1. Developing Innovative Ways of Incorporating Industry 5.0 Technologies Such as AI, IoT, and Robotics into the Education Sector to Improve Learning Outcomes*

This direction of research involves exploring how to integrate Industry 5.0 technologies in education and develop innovative solutions that can improve learning outcomes. This can include developing intelligent tutoring systems, virtual and augmented reality tools, and interactive learning environments that utilize AI and IoT technologies.

### *6.2. Investigating the Impact of Industry 5.0 Technologies on the Teaching and Learning Process and Identifying Strategies to Optimize Their Effectiveness*

This direction of research involves evaluating how Industry 5.0 technologies impact the teaching and learning process and identifying strategies to optimize their effectiveness. This can include analyzing how these technologies affect student engagement, motivation, and learning outcomes and identifying best practices for incorporating them into teaching methods.

### *6.3. Exploring the Potential of Industry 5.0 Technologies to Personalize Learning and Adapt to Individual Student Needs and Preferences*

This direction of research involves investigating the potential of Industry 5.0 technologies to personalize learning and adapt to individual student needs and preferences. This can include developing adaptive learning systems that utilize AI and IoT technologies to tailor the learning experience to each student's individual strengths and weaknesses.

### *6.4. Evaluating the Effectiveness of Industry 5.0 Technologies in Promoting Critical Thinking, Creativity, and Problem-Solving Skills among Students*

This direction of research involves analyzing how Industry 5.0 technologies can be used to promote critical thinking, creativity, and problem-solving skills among students. This can include developing learning activities and environments that foster these skills and evaluating their effectiveness in improving student learning outcomes.

*6.5. Examining the Impact of Industry 5.0 on Teacher Roles and Responsibilities and Identifying Strategies to Effectively Support and Train Educators*

This direction of research involves analyzing how Industry 5.0 technologies impact teacher roles and responsibilities, and identifying strategies to support and train educators effectively. This can include identifying new competencies and skills that educators need to effectively incorporate these technologies into their teaching practice and developing training programs and resources to support them.

*6.6. Investigating the Ethical and Social Implications of Industry 5.0 Technologies in Education, including Issues Related to Privacy, Bias, and the Digital Divide, and Identifying Strategies to Address These Concerns While Ensuring the Equitable and Ethical Implementation of Industry 5.0 in Education*

This direction of research involves analyzing the ethical and social implications of Industry 5.0 technologies in education and identifying strategies to address concerns related to privacy, bias, and the digital divide. This can include developing ethical guidelines and standards for the use of these technologies in education and identifying strategies to ensure equitable access to them for all students.

## 7. Contribution

This manuscript offers a significant contribution to the discourse on the pivotal intersection of smart education and Industry 5.0. It is designed to provide a comprehensive analysis of the automation of smart education, examining its key components, technological aspects, implications, challenges, and ethical considerations within the context of Industry 5.0. The primary objectives and the scope of this review paper lay the foundation for its key contributions.

Firstly, this manuscript contributes by illuminating the key components of smart education, including intelligent tutoring systems, adaptive learning environments, learning analytics, and the application of the Internet of Things (IoT) in education. By doing so, it offers educators, policymakers, and industry stakeholders an in-depth understanding of the fundamental elements that constitute smart education.

Secondly, the paper delves into the realm of automation technologies in smart education, particularly emphasizing the transformative role of advanced technologies such as artificial intelligence (AI), machine learning (ML), robotics, and augmented and virtual reality (AR/VR). This exploration outlines how these technologies have the potential to reshape and personalize learning experiences, enhancing their relevance and effectiveness in the context of Industry 5.0.

Thirdly, the paper contributes by thoroughly investigating the integration of smart education within Industry 5.0. The focus is on collaborative learning, human–robot interaction, competency-based education, skills assessment, and corporate partnerships. This analysis underscores the vital role smart education plays in preparing the global workforce to thrive in an era characterized by human–machine collaboration and evolving workforce demands.

Furthermore, the manuscript acknowledges the complexities and ethical considerations related to the implementation of smart education, including data privacy, the digital divide, teacher and student readiness, and potential biases in AI-driven systems. The paper offers insights into responsible and equitable adoption practices by addressing these concerns. In addition, the paper makes a substantial contribution by outlining future directions and research opportunities in the realm of smart education. It underscores the importance of continuous improvement and the integration of new technologies to ensure that education remains dynamic, adaptable, and effective in the context of Industry 5.0.

The motivation behind this manuscript arises from several key factors, including the rapid pace of technological advancements, evolving workforce demands, the need for lifelong learning, the necessity to address challenges and ethical considerations, the encouragement of collaboration and innovation, and the identification of future research opportunities. These motivating factors collectively contribute to a comprehensive under-

standing of the role and significance of smart education in Industry 5.0, providing valuable insights and guidance for educators, policymakers, and industry stakeholders as they navigate the evolving landscape of education in the digital age.

## 8. Limitations and Managerial Learnings

This section addresses the limitations of the study, recognizing the challenges posed by the breadth of the topic, potential generalizations, and evolving data. It also delves into the managerial learnings derived from the analysis of smart education within the context of Industry 5.0. These insights are intended to guide educational leaders and managers in preparing for the future of education, as well as to provide actionable recommendations for navigating the dynamic landscape of Industry 5.0. Understanding these limitations and applying the managerial learnings is vital for optimizing the impact and effectiveness of smart education initiatives and ensuring that education remains adaptable, inclusive, and aligned with the demands of this new industrial era.

### *8.1. Limitations*

- Scope and depth: one of the primary limitations of this paper is the vast scope of the topic. While it aims to provide a comprehensive analysis of smart education within the context of Industry 5.0, the complexity and breadth of the subject matter mean that certain aspects may not be covered in the depth they deserve. This limitation necessitates future research to delve deeper into specific areas of smart education;
- Generalization: the insights and recommendations presented in this paper may not be universally applicable due to regional, cultural, and institutional differences. The effectiveness of smart education strategies can vary significantly depending on the local context, and this paper provides a broad overview that might not address all the nuances of different educational ecosystems;
- Data availability: as of my knowledge cutoff date in January 2022, there may be recent developments, emerging technologies, or specific case studies that are not included in this paper. Therefore, readers should consult more recent sources for the latest information on smart education and Industry 5.0.

### *8.2. Managerial Learnings*

- Prioritizing technology integration: managers and educational leaders should recognize that technology integration is not an option but a necessity in modern education. The Industry 5.0 landscape demands that educational institutions prioritize the integration of smart technologies to remain relevant and effective;
- Continuous professional development: managers in educational institutions need to focus on the continuous professional development of educators. This involves providing training and support to ensure that teachers and instructors are well-equipped to navigate the challenges and opportunities presented by smart education;
- Strategic partnerships: collaboration with industry partners is crucial. Industry 5.0 encourages the integration of education and industry, and educational institutions should establish strategic partnerships with businesses to ensure that curricula are aligned with workforce needs;
- Ethical considerations: it is essential to be mindful of the ethical considerations associated with smart education, such as data privacy and bias in AI systems. Managers should implement policies and practices that prioritize ethical use of technology in education;
- Customization and personalization: smart education allows for customized and personalized learning experiences. Managers should explore ways to tailor educational programs to individual learner needs, enhancing engagement and outcomes.
- Agility and adaptability: in the dynamic landscape of Industry 5.0, the ability to adapt to new technologies and teaching methods is crucial. Managers should foster a

culture of adaptability and encourage experimentation with innovative approaches to education;
- Inclusivity: the digital divide and accessibility issues should be on the radar of educational managers. It is essential to ensure that all students have equal access to smart education tools and resources;
- Research and development: given the rapid pace of technological advancements, investment in research and development is key. Educational institutions should allocate resources to stay at the forefront of emerging technologies and pedagogical methods;
- International collaboration: collaborating with educational institutions worldwide can provide valuable insights and share best practices. Industry 5.0 is a global phenomenon, and learning from international partners can enrich the educational experience;
- Monitoring and evaluation: implementing smart education initiatives should be accompanied by robust monitoring and evaluation processes. Managers should regularly assess the impact of these initiatives on student outcomes and make data-driven improvements.

In conclusion, recognizing the limitations of the paper and embracing the managerial learnings it offers can help educational institutions adapt to the transformative era of Industry 5.0 and smart education. The key is to remain agile, ethical, and technology-focused while continually improving and customizing education to meet the demands of the future workforce.

## 9. Conclusions

In conclusion, this review delved deeply into the nexus of smart education and Industry 5.0, underscoring the pivotal function of modern automation in shaping an agile future workforce. Harnessing the prowess of advanced technologies like AI, ML, robotics, and AR/VR can redefine the contours of educational experiences, making them more tailored, immersive, and geared towards fostering adaptability and a culture of continuous learning.

Yet, as we tread this promising path, we must remain vigilant and address the multi-faceted challenges that lurk—issues encompassing data privacy, bridging the digital divide, ensuring preparedness among educators and students, and mitigating biases inherent in AI frameworks. By showcasing exemplary initiatives and case studies, this review serves as a clarion call for synergistic collaborations among educators, decision-makers, and industry influencers, spurring innovation and efficacious strategies.

Furthermore, by spotlighting emergent paradigms, anticipatory directions, and ripe avenues for research in smart education, the paper accentuates the imperativeness of evolution and tech assimilation to keep education attuned to the requisites of Industry 5.0. This review, in essence, amplifies the discourse on smart education automation, illuminating its indispensable role in sculpting a workforce ready for the imminent challenges and opportunities.

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**Data Availability Statement:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

**Conflicts of Interest:** The author declares no conflicts of interest.

## Appendix A. Literature Analysis

| Authors | Paper | Abstract Summary | Main Findings | Question-Relevant Summary |
|---|---|---|---|---|
| [41] | From Industry 4.0 towards In-dustry 5.0: A Review and Analysis of Paradigm Shift for the People, Organization and Technology | The main research aims from sustainability towards hu-man-centricity are emphasized in the movement towards In-dustry 5.0. | • Industry 5.0 is a complement to the existing Industry 4.0 paradigm, with an emphasis on the role of the worker in the production process.<br>• The main drivers and enablers for the introduction of these new paradigms are discussed.<br>• There is a significant shift in re-search aims from sustainability to hu-man-centricity. | The possible effects of Industry 5.0 on the education sector involve a shift in primary research objectives from sustainability to a human-centric focus. |
| [42] | Consequences of Industry 4.0 on Human Labor and Work Organisation | Industry 4.0 would lead to a substantial decrease in standardized low-skill and an increase in high-skill activities. | • Industry 4.0 will lead to a decrease in standardized low-skill and an increase in high-skill activities.<br>• Growing complexity in job profiles and the need for cross-functional work organization and cross-company partner networks.<br>• Growing importance of continuous learning, training, and education to adapt to future qualification require-ments. | The potential impacts of Industry 5.0 on the education sector include a substantial decrease in standardized low-skill and an increase in high-skill activities, embracing planning, control, and IT-related tasks. |
| [43] | Consequences of Industry 4.0 in Business and Economics | The aspects of work and skills development, smart technology adoption, intelligent manufacturing, and digitalization are well described. | • Work and skills development, smart technology adoption, intelligent manufacturing, and digitalization are well described.<br>• Government and its policies usu-ally play a supportive role.<br>• Studies lack a coherent view of the topic and solve partial questions. | The potential impacts of industry 5.0 on the education sector include work and skills development, smart technology adoption, intelligent manufacturing, and digitalization. |
| [44] | Adapting Universities for Sustainability Education in Industry 4.0: Channel of Challenges and Opportunities | Universities, which have historically shaped future talents and societal trends, must now update and modernize their programs, facilities, and infrastructure. | • Universities need to harness their core competencies to capitalize on the opportunities presented by Industry 4.0.<br>• Essential prerequisites for univer-sities in the era of Industry 4.0 encom-pass robust financial strategies, profi-cient staff, expanded industrial collabo-rations, upgraded infrastructure, updat-ed curricula, and enriching workshops.<br>• Adopting digital technologies within university settings is crucial to equip students with the necessary skills and a competitive edge for Industry 4.0. | The implications of Industry 5.0 for the educational sector encompass the demand for strategic financial planning, competent personnel, enhanced industry collaborations, state-of-the-art infrastructure, updated syllabuses, and meaningful workshops. |

| Authors | Paper | Abstract Summary | Main Findings | Question-Relevant Summary |
|---|---|---|---|---|
| [45] | A Comparative Study of Industry 4.0 with Education 4.0 | The use of automated processes has made education change from the mainstream methods to the path of how modern education should look like. | • The Fourth Industrial Revolution (IR 4.0) has led to the development of the industry at an extreme pace, with the use of technology and automated systems.<br>• Education 4.0 has been developed to comply with the advancements of the industry, with the use of automated processes and modern methods of edu-cation.<br>• This paper provides a comparative study of the revolutions led in the fields of both education and industry. | The potential impacts of Industry 5.0 on the education sector include the use of automated processes, the growth of the Fourth Industrial Revolution or IR 4.0, and the study of the Industrial Revolution 4.0. |
| [46] | A Perspective on Education to Support Industry 4.0: A Qualitative Case Study in UK | The gap between the industry's needs and competencies offered generally by education is revealing the increasing need to find new educational models to face the future. | • Four main issues were identified, which are the characteristics of the fu-ture workforce, students' readiness to work, expectations of different roles played at the tertiary education level, and awareness of the latest trends.<br>• Employers, academic practitioners, and students need to work together to face the upcoming challenges and fast-changing technologies.<br>• An interactive system should be provided as a platform for these three different parties to play their roles. | The potential impacts of Industry 5.0 on the education sector include the need to find new educational models to face the future, the need for an interactive system for employers, academic practitioners, and students to play their roles, and the awareness of the latest trends. |
| [47] | Education, Competences-Labor Market Analysis Against the Challenges of Industry 4.0 Economy | The current education system should be changed so engineers acquire more managerial skills. | • Industry 4.0 requires employees to have both technical and managerial skills, which means that the current ed-ucation system needs to be adapted to meet these needs.<br>• The labor market in Poland and Europe is currently facing challenges due to the changes brought about by Industry 4.0.<br>• Education must be adapted to meet the needs of the labor market in order to ensure a strong economy. | The potential effects of Industry 5.0 on the education sector encompass the necessity for employees to com-prehend both technical require-ments and aspects unrelated to the manufacturing process. |

| Authors | Paper | Abstract Summary | Main Findings | Question-Relevant Summary |
| --- | --- | --- | --- | --- |
| [48] | Knowledge Management—Education in the Light of Industry 4.0 | The available technical educa-tion programs in the field of industrial engineering ade-quately align with economic preferences related to em-ployment. | • Preparing the younger generation for the expectations set by the market, driven by the adoption of the Industry 4.0 concept, is imperative.<br>• The technical education offerings, particularly in the realm of Industrial Engineering, fall short of adequately meeting the economic employment preferences.<br>• Conducting data analysis to evalu-ate the effectiveness of the education system is crucial in determining the de-velopmental path for pupils and stu-dents. | The implications of Industry 5.0 for the education sector encompass educating the younger generation with a focus on equipping them with the skills to manage their knowledge effectively in the evolving economy. |
| [49] | Industry 5.0—The Expected Impact Of Next Industrial Revolution | Companies have not recognized the next Industrial Revolution because of the lack of entrepreneurship and transformation capacity related to Industry 4.0. | • Companies are still struggling to digitalize their business through the in-tegration of AI, IoT, and cloud technolo-gies.<br>• Industry 5.0 will bring a new level of automation and integration of human workers into the supply chain.<br>• Companies lack the transformation capacity and entrepreneurship to recog-nize and prepare for the next Industrial Revolution. | The potential impacts of Industry 5.0 on the education sector include the integration of artificial intelligence (AI), the Internet of Things (IoT), and cloud technologies. |
| [50] | Industry 4.0: Changes in Work Organization and Qualification Requirements—Challenges for Academic and Vocational Education | The technological advancements that drive changes in qualification requirements also enhance the capacity to fulfill those requirements. | • Digitalization in the workforce initiates transformative processes, giving rise to shifts and fresh demands in qual-ifications.<br>• Curricula must align with the evolving requisites of digitalization within the altered organizational framework of Industry 4.0.<br>• The technological progress driving shifts in qualification requirements also augments the capacity to fulfill these demands, thus giving rise to the concept of a digital signature pedagogy. | The potential ramifications of Industry 5.0 on the education sector encompass the following: alterations in requisite qualifications, the emergence of novel qualification configurations, and an augmented capacity to satisfy these demands. |

| Authors | Paper | Abstract Summary | Main Findings | Question-Relevant Summary |
|---|---|---|---|---|
| [51] | Industry 4.0 and Society 5.0: Opportunities and Threats | The tools and technological innovations forged by Industry 4.0 are poised to play a substantial role in enhancing the quality of life within society. | • Industry 4.0 holds the potential to transform industrial production by bol-stering operational efficiency and fos-tering the creation of innovative busi-ness models, services, and products.<br>• Society 5.0 centers around har-nessing the tools and technologies pio-neered by Industry 4.0 for the better-ment of humanity.<br>• Society 5.0 aims to leverage the advanced technology of Industry 4.0 for the well-being of humankind, fostering connectivity between individuals and systems in the digital realm, with opti-mization facilitated by artificial intelli-gence. | The implications of Industry 5.0 for the education sector encompass the emergence of novel business models, services, and products, the utilization of tools and technologies forged by Industry 4.0 for the betterment of humanity, and the repositioning of humans at the core of innovation, technological evolution, and industrial automation. |
| [52] | Effects of Industry 4.0 on Vocational Education and Training (ITA manuscript 15-04) | The system of dual vocational education and training has a high, almost unique significance in Germany and Austria. | • Industry 4.0 has the potential to significantly change the core areas of industrial manufacturing work.<br>• The dual vocational education and training system is well-suited to meet the new competency and qualification requirements of Industry 4.0.<br>• Recommendations for policymak-ers, companies, and social partners are outlined to ensure successful imple-mentation of Industry 4.0. | The potential impacts of Industry 5.0 on the education sector include changes in the core areas of industrial manufacturing work and a focus on the dual vocational education and training system. |
| [53] | Characteristics of Learning in The Era of Industry 4.0 and Society 5.0 | Learning characteristics in the era of Industry 4.0 and Society 5.0 are rapidly changing and need to be accommodated in the teaching and learning processes in higher education institutions. | • Learning characteristics in the era of Industry 4.0 and Society 5.0 are rapid-ly changing and need to be accommo-dated in the teaching and learning pro-cesses in higher education institutions.<br>• Focus group discussion (FGD) was used to obtain thematic data from vari-ous stakeholders, including the govern-ment, study program association, indus-try/corporations, university administra-tors/leaders, lecturers, students, and alumni.<br>• The purpose of this study was to analyze the characteristics of learning in the era of Industry 4.0 and Society 5.0, specifically in the Masters Program of Education Technology of a private uni-versity in Jakarta. | The potential impacts of Industry 5.0 on the education sector include rapidly changing learning characteristics that need to be accommodated in the teaching and learning processes in higher education institutions. |

| Authors | Paper | Abstract Summary | Main Findings | Question-Relevant Summary |
|---|---|---|---|---|
| [54] | Aspects regarding skills and education related to Industry 4.0 | The skills required by Industry 4.0 are constantly changing. | • Industry 4.0 requires new skills and competencies, which can be ob-tained through Education 4.0.<br>• Education systems need to adapt to the changing requirements of Industry 4.0.<br>• Education and industry need to work together to ensure that everyone can benefit from technological progress. | The potential impacts of Industry 5.0 on the education sector include digitalization and VR, AR, CPS, IoT, ICT, AI assures higher precisions, higher productivity, mass customization, less waste and less pollution, and contributes to societal change. |
| [55] | Industry 4.0: University Students' Perception, Awareness and Preparedness—A Case of Namibia | Students are aware of Industry 4.0. | • Students in Namibia are aware of Industry 4.0, but need further education on its applications to be prepared for the revolution.<br>• Most students have used Industry 4.0 applications and are competent in using them.<br>• Relevant government bodies and schools need to put strategies in place to create further awareness of Industry 4.0. | The potential impacts of Industry 5.0 on the education sector include the need for further education on its applications. |
| [56] | Labor and Education Markets in Industry 4.0 | The newly emerging professions demand new profiles of graduates. | • Industry 4.0 requires a significant transformation of education and labor markets, due to the emergence of new professions demanding new profiles of graduates.<br>• A successful transition to Industry 4.0 requires the linkage between indus-trial policy and educational, scientific, technical, and innovation policies.<br>• Calls for changes in the education-al structure and new qualifications will be formulated regarding the Slovak economy by 2030. | The potential impacts of Industry 5.0 on the education sector include the need for a significant transformation of education and labor markets because newly emerging professions demand new profiles of graduates. |

| Authors | Paper | Abstract Summary | Main Findings | Question-Relevant Summary |
| --- | --- | --- | --- | --- |
| [57] | Industry 4.0 in Educational Process | Individual technologies are presented to students in the form of partial tasks that are mutually related. | • Industry 4.0 technologies are being introduced into the educational process of students of Bachelor and Master de-gree studies at the Faculty of Mechanical Engineering, Brno University of Tech-nology.<br>• Technologies such as sensor sys-tems, OPC UA data collection, data pro-cessing, metrology, simulation, automa-tion, robotics, M2M communication, virtual reality, and digital commission-ing are presented to students in the form of partial tasks.<br>• The result is an overall overview of the elements of Industry 4.0 and their implementation into production sys-tems. | The potential impacts of Industry 5.0 on the education sector include the introduction of individual technologies to students in the form of partial tasks that are mutually related. |
| [58] | The Impact of Industry 4.0 on Education and Future Jobs | Certain professions will become obsolete, while others will evolve, and entirely new job roles that are currently non-existent will become commonplace. | • Industry 4.0 will have a significant impact on the way education is deliv-ered and the skills required for future jobs.<br>• New jobs will be created, while some existing jobs will become obsolete.<br>• The skills required for future jobs will be more focused on digital trans-formation, such as data analysis, artificial intelligence, and machine learning. | The potential impacts of Industry 5.0 on the education sector include the development of new jobs, the requirement for new skills, and the transformation of modern living and working. |
| [59] | Technological Trends of Industry 4.0 in Education: Opportunity Navigator | Digital technologies define the direction and character of digital transformation within various industry sectors, including education. | • Digital technologies from the In-dustry 4.0 era span a spectrum of ap-plicability in education, ranging from active implementation to potential use.<br>• Big data, virtual and augmented reality, robotics, sensor technology, and artificial intelligence hold substantial promise for integration into the field of education.<br>• The digital evolution of education is imperative to enable its evolution into new forms and to enhance its quality, paving the way for Education 4.0. | The implications of Industry 5.0 for the education sector encompass the utilization of advanced technologies such as big data, virtual and augmented reality, robotics, sensor technology, and artificial intelligence. These technologies facilitate the establishment of data repositories, the adoption of novel learning models, the introduction of educational agents, and the implementation of personalized educational solutions. |

| Authors | Paper | Abstract Summary | Main Findings | Question-Relevant Summary |
|---|---|---|---|---|
| [60] | Relevansi Industri 4.0 dan Society 5.0 Terhadap Pendidikan Di Indonesia | The development of the Industrial Revolution 4.0 and 5.0 is expected to bring progress to the development of education, especially in Indonesia. | • The presence of the Industrial Revolution 4.0 and 5.0 has contributed significantly to Indonesian education.<br>• Technology-based learning inno-vations make it easier for students to learn without knowing space, time, and place.<br>• The development of the Industrial Revolution 4.0 and 5.0 is expected to bring progress to the development of education, especially in Indonesia, by creating change and preparing superior and innovative graduates with skills that have been prepared in advance. | The potential impacts of Industry 5.0 on the education sector include the existence of technology-based learning innovations that make it easier for students to learn without knowing space, time, and place. |
| [61] | Industry 4.0 and Educational Strategies | The factors associated with companies' training strategies and employees' educational attainment have the greatest power to explain high levels of firms' educational match. | • A set of factors associated with companies' training strategies and em-ployees' educational attainment have the greatest power to explain high levels of firms' educational match.<br>• A set of factors leading to firms' educational mismatch were identified.<br>• Policy implications for educational interventions to support Industry 4.0 were highlighted. | N/A |
| [62] | Industrial engineering curriculum in industry 4.0 in a South African context | The focus has transitioned from conventional industrial engineering techniques to data-driven processes and cyber-physical systems within the scope of Industry 4.0. | • Industry 4.0 holds the potential to substantially alter the knowledge and skill prerequisites for industrial engi-neers.<br>• The emphasis has shifted from conventional industrial engineering ap-proaches to data-driven functions and cyber-physical systems.<br>• In South Africa, only a single uni-versity has made advancements in im-plementing an Industry 4.0 infrastruc-ture. | The implications of Industry 5.0 for the education sector encompass the necessity to reevaluate the role of industrial engineers to avert a more significant disruption than the identity crisis prompted by information technology in the 1990s. Additionally, the focus has shifted from conventional industrial engineering techniques to data-driven processes and cyber-physical systems. |

| Authors | Paper | Abstract Summary | Main Findings | Question-Relevant Summary |
|---|---|---|---|---|
| [63] | Sustainable engineering challenges towards Industry 4.0: A comprehensive review | Industry 4.0 affects the production environment by introducing new technologies which require a better-educated workforce. | • Industry 4.0 brings new technolo-gies which require a better-educated workforce and changes in curricula and teaching methods.<br>• It brings new challenges and re-quires a new approach from manage-ment to handle fast and big changes in the business environment.<br>• It requires effective implementa-tion of innovation in production. | The potential impacts of Industry 5.0 on the education sector include the need for a better-educated workforce and changes in curricula and ways of teaching. |
| [64] | Trends and prospects for IT education in Industry 4.0 | Future engineers need to improve their professional, social, methodological and personal competencies. | • Industry 4.0 has brought about changes in the education system, driven by artificial intelligence and digital physical structures.<br>• Education 4.0 technologies play an important role in supporting Industry 4.0 and have a significant impact on the change in IT education.<br>• Future engineers need to improve their professional, social, methodologi-cal, and personal competencies to suc-cessfully complete production tasks. | The potential impacts of Industry 5.0 on the education sector include the need for future engineers to improve their professional, social, methodological, and personal competencies. |
| [65] | Industry 4.0 and its Potential Impact on Employment Demographics in the UK | Educational systems seem to be lagging in their ability to promptly address the future workforce needs brought about by Industry 4.0. | • Industry 4.0 represents a trans-formative shift within the manufactur-ing sector, anticipated to exert a signifi-cant influence on the industry.<br>• Educational systems are struggling to keep pace with the evolving labor demands posed by Industry 4.0.<br>• This underscores the necessity for in-depth examination and the identifica-tion and fulfillment of the educational prerequisites essential for future em-ployment in a post-Industry 4.0 land-scape. | The implications of Industry 5.0 for the education sector involve the necessity for a highly adaptable education system to cultivate the workforce needed for the upcoming era of Industry 4.0. |

| Authors | Paper | Abstract Summary | Main Findings | Question-Relevant Summary |
| --- | --- | --- | --- | --- |
| [66] | Industry 4.0 and the Challenges Faced by STEM Education | The skills required by industrial automation engineers are a challenge for STEM education. | • Industry 4.0 is a paradigm that re-quires new skills and knowledge from industrial automation engineers.<br>• STEM education must be adapted to meet the challenges posed by Industry 4.0.<br>• There is a need to create a corre-spondence between the required skills and the taught subjects in STEM educa-tion. | The potential impacts of Industry 5.0 on the education sector include the main factors supporting the implementation of the paradigm Industry 4.0, their basic characteristics, which represent challenges in front of the STEM education, and some tasks faced by the industrial automation engineers. |
| [67] | Industry 4.0 and Science Education | Nations incapable of adjusting to Industry 4.0 processes will struggle to advance scientifically, technologically, and to remain competitive in ongoing innovation endeavors. | • Industry 4.0 encompasses a wide array of contemporary automation pro-cedures, interlinked vast databases, ro-botic systems, and advanced manufac-turing technologies aimed at ensuring high-quality production.<br>• Industry 4.0 integrates cutting-edge technologies such as addi-tive manufacturing, autonomous robot-ics, big data, artificial intelligence, aug-mented reality, system integration, the Internet of Things, cybersecurity, cloud computing, machine learning, deep learning, and more.<br>• Science education is intricately linked to Industry 4.0, as a comprehen-sive understanding and proficiency in utilizing these technologies are essential for success in the context of the Fourth Industrial Revolution. | The implications of Industry 5.0 for the education sector encompass the necessity for adaptability to Indus-try 4.0 processes. |
| [68] | Exploring the economic and social impacts of Industry 4.0 | Recent technological breakthroughs, including advanced robotics, artificial intelligence, big data analytics, augmented and virtual reality, the Internet of Things, and 3D printing are seen as set to change the way we work and live. | • Industry 4.0 is set to revolutionize the way we work and live through the use of advanced robotics, artificial intel-ligence, big data analytics, augmented and virtual reality, the Internet of Things (IoT), and 3D printing.<br>• Industry 4.0 is expected to have both economic and social impacts, in-cluding increased productivity, im-proved customer experience, and new job opportunities.<br>• The implementation of Industry 4.0 will require significant investment in infrastructure, training, and research and development. | N/A |

| Authors | Paper | Abstract Summary | Main Findings | Question-Relevant Summary |
| --- | --- | --- | --- | --- |
| [69] | External Partnerships in Employee Education and Development as the Key to Facing Industry 4.0 Challenges | Organizations stand to gain from incorporating emerging knowledge continuously into their internal environments in the near future. | • The Fourth Industrial Revolution will necessitate organizations to collab-orate with external partners, fellow or-ganizations, and educational institutions to integrate new knowledge into their internal environment seamlessly.<br>• Innovations play a pivotal role in adapting to significant environmental shifts, including educational processes.<br>• A notable difference in strategic employee education and development approaches exists between highly inno-vative countries and those with moder-ate innovation levels. | The implications of Industry 5.0 for the education sector encompass the necessity for collaboration with the external environment, fostering fresh educational opportunities rooted in partnerships with external entities, organizations, and educa-tional institutions. |
| [70] | Industry 4.0 Manpower and its Teaching Connotation in Technical and Vocational Education: Adjust 107 Curriculum Reform | The original teaching contents in the junior college departments have been changed, and departments have been recombined to meet the demands of Industry 4.0. | • Technical and vocational education has been adjusted to include courses re-lated to big data analysis, cloud compu-ting, and Internet of Things.<br>• Higher vocational education has established a practical classroom based on the concept of Industry 4.0.<br>• Industry and schools have estab-lished a close cooperation relationship and share resources with each other. | The potential impacts of Industry 5.0 on the education sector include the need for updated equipment and curricula to match the demands of the industry, as well as closer cooperation between schools and industry. |
| [71] | Educational methods for Industry 4.0 | The use of small-scale models is effective in practical training. | • Industry 4.0 requires changes in the labor market, with new competen-cies required for employees.<br>• Small-scale models can be used to demonstrate new ways of operation management in practical training.<br>• These models behave practically the same as in actual operation, allowing students to try out different production states, problem-solving, and subsequent optimization. | The potential impacts of Industry 5.0 on the education sector include the need for new technologies, climate change, and the pandemic of the disease caused by the new coronavirus COVID-19. |

| Authors | Paper | Abstract Summary | Main Findings | Question-Relevant Summary |
| --- | --- | --- | --- | --- |
| [72] | The Fourth Industrial Revolution—its impact on vocational skills | The vocational education system must align with the evolving demands and anticipations of the evolving work landscape. | • Industry 4.0 represents the pre-vailing shift toward automation and data exchange in manufacturing technolo-gies, underpinned by digital advance-ments.<br>• Industry 4.0 will bring about changes in the qualification prerequisites for employees both at the shop-floor level and in mid-level positions.<br>• Vocational education and training for the workforce must be tailored to align with the requisites and anticipa-tions of Industry 4.0. | The implications of Industry 5.0 for the education sector involve the development of curricula and the training of both skilled and highly skilled workers. |
| [73] | Technology trends, Education 4.0 and beyond | Companies and institutions with robust information and technology infrastructure must possess specific skills to effectively integrate advanced digital technologies into their innovation and production processes. | • Education 4.0 mirrors the era of Industry 4.0, necessitating proficiency in 21st-century skills.<br>• Evolving technology trends have reshaped educational paradigms and instructional methods.<br>• The incorporation of information and communication technology (ICT) in education is imperative to unlock the potential of smart products, services, and business prospects. | The implications of Industry 5.0 for the education sector encompass the imperative need for a comprehensive overhaul of education systems to supply the skilled workforce demanded by this dynamic progression. |
| [74] | University 4.0: The Industry 4.0 paradigm applied to Education | In educational institutions striving to meet the demand for enhanced, streamlined, and personalized large-scale technology-enabled education, technology has become omnipresent. | • The University 4.0 concept draws inspiration from the Industry 4.0 para-digm and applies its principles to higher education, aiming to offer more tailored solutions to the unique requirements of each learner.<br>• Technology has permeated educa-tional institutions as they strive to meet the increasing demand for enhancement, efficiency, and individualization in large-scale, technology-enhanced educa-tion.<br>• There exists a necessity to recon-sider and reformulate the approach to technology integration in education to realize intelligent collaboration and co-ordination between technology and in-dividuals in the pursuit of effective learning. | The implications of Industry 5.0 for the education sector necessitate reevaluating and reshaping the technology integration model in teaching to attain intelligent collaboration and seamless coordination between technology and individuals in the context of learning. |

| Authors | Paper | Abstract Summary | Main Findings | Question-Relevant Summary |
|---|---|---|---|---|
| [75] | Impact of 5G Technologies on Industry 4.0 | 5G promises to be a key enabler for Factories of the Future. | • Industry 4.0 encompasses the inte-gration of Internet of Things (IoT), ana-lytics, additive manufacturing, robotics, artificial intelligence, advanced materi-als, and augmented reality.<br>• 5G technologies serve as a pivotal catalyst for the evolution of Factories of the Future, offering a unified communi-cation platform essential for pioneering new business models and addressing the limitations of current communication technologies.<br>• The advent of 5G technologies will exert a substantial influence on the pro-gression of the industrial revolution and the technologies that have played a role in their advancement. | The implications of Industry 5.0 for the education sector encompass the integration of the Internet of Things (IoT), analytics, additive manufacturing, robotics, artificial intelligence, advanced materials, and augmented reality. |
| [76] | The Changing Role of Engineering Education in Industry 4.0 Era | The characteristics of knowledge and skills provided in these departments are yet to be revealed through objective evaluation. | • Engineering departments have a vital role in fulfilling the new education requirements of Industry 4.0.<br>• A precise classification of knowledge and skills areas offered in these departments is needed to deter-mine the emerging patterns in the deliv-ery of new education requirements.<br>• A sample of 124 engineering de-partments was studied to reveal the emerging patterns and similarities in engineering education to cover this need. | N/A |
| [77] | Industry 4.0 paradigm on teaching and learning engineering | The performance of Industry 4.0 education tools was evaluated in a real context. | • The proposed Industry 4.0 educa-tion tools, based on e-learning and cyber-physical technologies, were suc-cessfully deployed in subjects related to microcontroller programming in Tele-communication Engineering and Bioen-gineering degree programs.<br>• Results showed an improvement in the students' motivation, their academic results, and their acquisition of Industry 4.0 competencies.<br>• The early adoption of Industry 4.0 tools and methods had a positive impact on engineering education. | The potential impacts of Industry 5.0 on the education sector include the improvement in the student's motivation, their academic results, and their acquisition of Industry 4.0 competencies. |

| Authors | Paper | Abstract Summary | Main Findings | Question-Relevant Summary |
| --- | --- | --- | --- | --- |
| [78] | Education in the Era of Industry 4.0 | Industry 4.0 has changed the thinking of industry owners in terms of technological usage. | • Qualifications needed to fit in the smart factory era of Industry 4.0.<br>• Challenges that emerge in educa-tion to implement skills suitable for In-dustry 4.0.<br>• Opportunities for the education sector as far as the smart factory is con-cerned. | The potential impacts of Industry 5.0 on the education sector include preparing skilled people compatible with Industry 4.0, implementing skills suitable for Industry 4.0, and providing opportunities for the education sector as far as the smart factory is concerned. |
| [79] | The Future of Product Design Education Industry 4.0 | The pace of change in the current digital revolution driving Industry 4.0 can inhibit a proactive, rather than reactive response. | • Product design is uniquely posi-tioned at the nexus of engineering and the humanities and is directly tied to changes affecting manufacturing in the fourth industrial revolution.<br>• Educational leadership must de-velop proactive strategies to respond to the challenges and opportunities of In-dustry 4.0 to inform the future of work, industry, and society.<br>• Historical perspective and twen-ty-first-century knowledge can help to plan for a healthy society and the future of work in the digital revolution. | The potential impacts of Industry 5.0 on the education sector include the development of proactive strategies to respond to the challenges and opportunities of Industry 4.0. |
| [80] | Industry 4.0 and the digital transformation. . . A new challenge for higher education | The implementation of various technological tools will allow students to be better prepared when entering their professional life. | • Technology has created a need for educational improvements in order to prepare students for better job, profes-sional, and personal opportunities.<br>• Technology can be used to improve the management of information and production, which is applicable in vari-ous functional areas of any organization.<br>• Inclusive education focused on managing processes can help to form significant changes in students, improv-ing their study habits and preparing them to be better professionals. | The potential impacts of Industry 5.0 on the education sector include the implementation of various technological tools to allow students to be better prepared when entering their professional lives. |

| Authors | Paper | Abstract Summary | Main Findings | Question-Relevant Summary |
|---|---|---|---|---|
| [81] | The Impact of Industry 4.0 on the Labor Market | Automation and robotization is an opportunity for more efficient and friendlier workplaces for employees. | • Industry 4.0 has changed the na-ture of many jobs and created new ones, providing new opportunities for em-ployees with qualifications and skills related to new technologies.<br>• Automation and robotization can lead to more efficient and friendlier workplaces, and greater profits for em-ployers.<br>• The jobs of the future require both technological savvy and human skills. | N/A |
| [82] | Industry 4.0 and Engineering Education: An Analysis of Nine Technological Pillars Inclusion in Higher Educational Curriculum | Engineering currica have subjects that contribute directly to the pillars of Industry 4.0. | • Engineering curricula have sub-jects that contribute directly to the pil-lars of Industry 4.0, but some are missed or not entirely defined.<br>• It is required to establish regula-tions in Mexico that encourage the actu-alization and modifications of educa-tional programs in higher education in-stitutions to meet the new technological knowledge required by the industry in this new digital age.<br>• The universities analyzed in this paper are the most important in the Nuevo Leon State and from the premise that it is very important to Mexico from the industrial perspective. | The potential impacts of Industry 5.0 on the education sector include the need for new regulations to encourage the actualization and modifications of educational programs in higher education institutions to meet the new technological knowledge required by the industry in this new digital age. |
| [83] | Industry 5.0: Is the Manufacturing Industry on the Cusp of a New Revolution? | The fifth industrial revolution is poised to reshape the trajectory of industry, building upon the foundations established by the tools of Industry 4.0. | • The Fifth Industrial Revolution is poised to instigate a transformative paradigm shift within the manufactur-ing industry, building upon the founda-tional tools of Industry 4.0.<br>• These tools encompass a spectrum of technologies such as the Internet of Things, digitization, blockchain, ad-vanced materials, additive manufactur-ing, artificial intelligence, robotics, drones, energy technology, biotechnol-ogy, neurotechnology, and virtual and augmented reality.<br>• Prior industrial revolutions were underpinned by essential components, including scientific and technological breakthroughs, education and training, and access to capital. | The implications of Industry 5.0 for the education sector encompass a paradigm shift in the trajectory of industrial evolution, building upon the foundational tools of Industry 4.0, which encompass the Internet of Things, digitization, blockchain, advanced materials, additive manufacturing, artificial intelligence, robotics, drones, energy technology, biotechnology, neurotechnology, and virtual and augmented reality. |

| Authors | Paper | Abstract Summary | Main Findings | Question-Relevant Summary |
|---|---|---|---|---|
| [84] | Critical Components of Industry 5.0 Towards a Successful Adoption in the Field of Manufacturing | The Fifth Industrial Revolution is required to provide better interaction with customers. | • Industry 5.0 focuses on personal-ized customer demand.<br>• It requires advanced technologies such as AI, IoT, and robotics.<br>• It requires a shift in organizational culture to be successful. | The potential impacts of Industry 5.0 on the education sector include better interaction. |
| [85] | Technological competitiveness and emerging technologies in industry 4.0 and industry 5.0. | Competencies and engineering skills are important in the personnel approach of developed economies. | • Developed economies emphasize competencies and engineering skills, R+D+i, and the use of emerging tech-nologies such as the Internet of Things and big data.<br>• Emerging economies emphasize training and education, sustainability and structure, and emerging technolo-gies such as the Internet of Things and digitalization. | The implications of Industry 5.0 for the education sector encompass the significance of competencies and engineering skills in personnel development, the role of R+D+i and the supply chain in organizational strategies, and the utilization of emerging technologies like the Internet of Things and big data. |
| [86] | Industry 4.0 and its Implementation: a Review | Industry 4.0 has garnered substantial interest from both the industrial and academic sectors. | • Industry 4.0 signifies a transforma-tive phase in the manufacturing indus-try, made possible by the advancements in information and communications technologies.<br>• The research pertaining to Indus-try 4.0 is progressing towards the crea-tion of frameworks that establish con-nections between Industry 4.0's enabling technologies, their objectives, and their influence on the operations of manufac-turers.<br>• There exist impediments to the adoption of Industry 4.0, and potential solutions for surmounting these chal-lenges and barriers are under discussion. | N/A |

| Authors | Paper | Abstract Summary | Main Findings | Question-Relevant Summary |
|---|---|---|---|---|
| [87] | Realizing Industry 4.0 Through STEM Education: But Why STEM Is Not Preferred? | The roles of the national workforce, including the education system, culture, and government, need to be fortified to elevate the STEM education system in Malaysia. | • A survey involving 102 Diploma in Accountancy students at a Malaysian public university was conducted to in-vestigate the determinants influencing university students' choices to pursue STEM education.<br>• Principal component analysis (PCA) identified factors responsible for 68.22% of the overall variance.<br>• Multiple regression analysis demonstrated that factors such as low morale attitude, learning experience, and return on investment accounted for 53% of the total variance in perception. | The implications of Industry 5.0 for the education sector encompass factors like low morale attitude, learning experience, and return on investment. |
| [88] | The Future with Industry 4.0 at the Core of Society 5.0: Open Issues, Future Opportunities and Challenges | Industry 4.0 focuses on the metamorphosis of all industrial components with the help of strong digital support. | • Industry 4.0 and Society 5.0 are closely linked and mutually beneficial.<br>• Industry 4.0 focuses on the digital transformation of industrial compo-nents, while Society 5.0 encourages a digital revamp of mundane life.<br>• The rapid change in information and communication technology, along with the portrayal of Society 5.0 as a global trend, are key aspects of the Sci-ence and Technology Basic plan. | N/A |
| [89] | Perceived Impacts of Industry 4.0 on Manufacturing Industry and Its Workforce: Case of Germany | Manufacturing processes will become more autonomous, integrated, and intelligent. | • Industry 4.0 will have a significant impact on the manufacturing industry, leading to increased automation and integration of processes.<br>• The manufacturing workforce will need to develop new skills and knowledge, such as software, program-ming, and interdisciplinary skills, in or-der to keep up with the changing indus-try.<br>• The introduction of Industry 4.0 will lead to changes in the way products are manufactured, as well as in the re-quirements for the manufacturing workforce. | The potential impacts of Industry 5.0 on the education sector include changes in requirements for the manufacturing workforce towards an increasing need for software, programming, and interdisciplinary skills. |

## References

1. Adel, A. Unlocking the Future: Fostering Human–Machine Collaboration and Driving Intelligent Automation through Industry 5.0 in Smart Cities. *Smart Cities* **2023**, *6*, 2742–2782. [CrossRef]
2. Maddikunta, P.K.R.; Pham, Q.-V.; Prabadevi, B.; Deepa, N.; Dev, K.; Gadekallu, T.R.; Ruby, R.; Liyanage, M. Industry 5.0: A survey on enabling technologies and potential applications. *J. Ind. Inf. Integr.* **2021**, *26*, 100257. [CrossRef]

3. Zhironkin, S.; Ezdina, N. Review of Transition from Mining 4.0 to Mining 5.0 Innovative Technologies. *Appl. Sci.* **2023**, *13*, 4917. [CrossRef]
4. Schwab, K. *The Fourth Industrial Revolution*; Penguin Group: London, UK, 2017.
5. European Commission. Directorate General for Research and Innovation. Enabling Technologies for Industry 5.0: Results of a Workshop with Europe's Technology Leaders. Publications Office. 2020. Available online: https://data.europa.eu/doi/10.2777/082634 (accessed on 5 November 2023).
6. Zhang, C.; Wang, Z.; Zhou, G.; Chang, F.; Ma, D.; Jing, Y.; Cheng, W.; Ding, K.; Zhao, D. Towards new-generation human-centric smart manufacturing in Industry 5.0: A systematic review. *Adv. Eng. Inform.* **2023**, *57*, 102121. [CrossRef]
7. Masoomi, B.; Sahebi, I.G.; Ghobakhloo, M.; Mosayebi, A. Do industry 5.0 advantages address the sustainable development challenges of the renewable energy supply chain? *Sustain. Prod. Consum.* **2023**, *43*, 94–112. [CrossRef]
8. Liu, S.; Chen, Y.; Huang, H.; Xiao, L.; Hei, X. Towards Smart Educational Recommendations with Reinforcement Learning in Classroom. In Proceedings of the 2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE), Wollongong, Australia, 4–7 December 2018; pp. 1079–1084.
9. Yu, H.; Miao, C.; Leung, C.; White, T.J. Towards AI-powered personalization in MOOC learning. *npj Sci. Learn.* **2017**, *2*, 1–5. [CrossRef] [PubMed]
10. Abu-Abed, F.; Zhironkin, S. New Game Artificial Intelligence Tools for Virtual Mine on Unreal Engine. *Appl. Sci.* **2023**, *13*, 6339. [CrossRef]
11. Mubin, O.; Stevens, C.J.; Shahid, S.; Al Mahmud, A.; Dong, J.-J. A review of the applicability of robots in education. *Technol. Educ. Learn.* **2013**, *1*, 13. [CrossRef]
12. Gan, B. Design and Application Research of VR/AR Teaching Experience System. In *Journal of Physics: Conference Series*; IOP Publishing: Bristol, UK, 2019; Volume 1187, p. 052079. [CrossRef]
13. Petrović, L.; Stojanović, D.; Mitrović, S.; Barać, D.; Bogdanović, Z. Designing an extended smart classroom: An approach to game-based learning for IoT. *Comput. Appl. Eng. Educ.* **2021**, *30*, 117–132. [CrossRef]
14. Hooda, M.; Rana, C.; Dahiya, O.; Rizwan, A.; Hossain, S. Artificial Intelligence for Assessment and Feedback to Enhance Student Success in Higher Education. *Math. Probl. Eng.* **2022**, *2022*, 5215722. [CrossRef]
15. Alojaiman, B. Technological Modernizations in the Industry 5.0 Era: A Descriptive Analysis and Future Research Directions. *Processes* **2023**, *11*, 1318. [CrossRef]
16. Palanivel, K. Emerging Technologies to Smart Education. *Int. J. Comput. Trends Technol.* **2020**, *68*, 5–16.
17. Zahabi, M.; Razak, A.M.A. Adaptive virtual reality-based training: A systematic literature review and framework. *Virtual Real.* **2020**, *24*, 725–752. [CrossRef]
18. Fu, L. Research on the Teaching Model of Animation Professional Class Based on AR/VR Technology and 5G Network. *Wirel. Commun. Mob. Comput.* **2021**, *2021*, 1715909. [CrossRef]
19. Benita, F.; Virupaksha, D.; Wilhelm, E.; Tunçer, B. A smart learning ecosystem design for delivering Data-driven Thinking in STEM education. *Smart Learn. Environ.* **2021**, *8*, 11. [CrossRef]
20. Gerhardtl, T.; Laitakari, A.; Rice, M.; Bhasham, C. Digital Trends in Education: Marketing of the Online Teaching. In *Integrated Business Models in the Digital Age: Principles and Practices of Technology Empowered Strategies*; Singh Dadwal, S., Jahankhani, H., Hassan, A., Eds.; Springer International Publishing: New York, NY, USA, 2022; pp. 425–466. [CrossRef]
21. Zhironkin, S.; Dotsenko, E. Review of Transition from Mining 4.0 to 5.0 in Fossil Energy Sources Production. *Energies* **2023**, *16*, 5794. [CrossRef]
22. Javaid, M.; Haleem, A.; Singh, R.P.; Haq, M.I.U.; Raina, A.; Suman, R. Industry 5.0: Potential Applications in COVID-19. *J. Ind. Integr. Manag.* **2020**, *05*, 507–530. [CrossRef]
23. Valeyeva, N.S.; Kupriyanov, R.V.; Valeeva, E.; Kraysman, N.V. Influence of the Fourth Industrial Revolution (Industry 4.0) on the System of the Engineering Education. In *The Impact of the 4th Industrial Revolution on Engineering Education*; Auer, M.E., Hortsch, H., Sethakul, P., Eds.; Springer International Publishing: New York, NY, USA, 2020; pp. 316–325. [CrossRef]
24. Carayannis, E.G.; Morawska-Jancelewicz, J. The Futures of Europe: Society 5.0 and Industry 5.0 as Driving Forces of Future Universities. *J. Knowl. Econ.* **2022**, *13*, 3445–3471. [CrossRef]
25. Oztemel, E.; Gursev, S. Literature review of Industry 4.0 and related technologies. *J. Intell. Manuf.* **2018**, *31*, 127–182. [CrossRef]
26. Baygin, M.; Yetis, H.; Karakose, M.; Akin, E. An effect analysis of industry 4.0 to higher education. In Proceedings of the 2016 15th International Conference on Information Technology Based Higher Education and Training (ITHET), Istanbul, Turkey, 8–10 September 2016; pp. 1–4.
27. Assante, D.; Caforio, A.; Flamini, M.; Romano, E. Smart Education in the context of Industry 4.0. In Proceedings of the 2019 IEEE Global Engineering Education Conference (EDUCON), Dubai, United Arab Emirates, 8–11 April 2019; pp. 1140–1145.
28. Maria, M.; Shahbodin, F.; Pee, N.C. Malaysian higher education system towards industry 4.0–Current trends overview. In Proceedings of the 3rd International Conference on Applied Science and Technology (ICAST'18), Penang, Malaysia, 10–12 April 2018; p. 020081.
29. Huba, M.; Kozak, S. From e-Learning to Industry 4.0. In Proceedings of the 2016 International Conference on Emerging eLearning Technologies and Applications (ICETA), Vysoke Tatry, Slovakia, 24–25 November 2016; pp. 103–108.
30. Mourtzis, D.; Angelopoulos, J.; Panopoulos, N. A Literature Review of the Challenges and Opportunities of the Transition from Industry 4.0 to Society 5.0. *Energies* **2022**, *15*, 6276. [CrossRef]

31. Umachandran, K.; Jurcic, I.; Ferdinand-James, D.; Said, M.M.T.; Rashid, A.A. Gearing up Education Towards Industry 4.0. *Int. J. Comput. Technol.* **2018**, *17*, 7305–7311. [CrossRef]
32. Benešová, A.; Tupa, J. Requirements for Education and Qualification of People in Industry 4.0. *Procedia Manuf.* **2017**, *11*, 2195–2202. [CrossRef]
33. Al Faruqi, U. Future Service in Industry 5.0. *J. Sist. Cerdas* **2019**, *2*, 67–79. [CrossRef]
34. The Impact of Industry 4.0 on Education Contents. *Verslas Teorija Ir Praktika* **2021**, *22*, 29–38. Available online: https://www.ceeol.com/search/article-detail?id=1008124 (accessed on 20 July 2023). [CrossRef]
35. Alias, S.Z.; Selamat, M.N.; Alavi, K.; Arifin, K. Industry 4.0: A Systematic Review in Technical and Vocational Education and Training. *J. Psikol. Malays.* **2018**, *32*, 4. Available online: https://spaj.ukm.my/ppppm/jpm/article/view/437 (accessed on 5 November 2023).
36. Beke, É. The Relationship and Interaction between Industry 4.0 and Education. *Műszaki Tudományos Közlemények* **2020**, *13*, 36–39. [CrossRef]
37. Tavares, M.C. Industry 4.0 contributions to Education 4.0. In Proceedings of the 2021 16th Iberian Conference on Information Systems and Technologies (CISTI), Chaves, Portugal, 23–26 June 2021.
38. Petrenko, A. Inevitable changes in the IT industry. Training in the conditions of the fifth industrial revolution (industry 5.0). *Syst. Res. Inf. Technol.* **2022**, *1*, 1. [CrossRef]
39. Muktiarni, M.; Widiaty, I.; Abdullah, A.G.; Ana, A.; Yulia, C. Digitalisation trend in education during industry 4.0. In *Journal of Physics: Conference Series*; IOP Publishing: Bristol, UK, 2019; Volume 1402. [CrossRef]
40. Saxena, A.; Pant, P.; Patel, C.; Quiriello, L. Emergence of Educators for Industry 5.0—An Indological Perspective. *Int. J. Innov. Technol. Explor. Eng.* **2020**, *9*, 359–363. [CrossRef]
41. Zizic, M.C.; Mladineo, M.; Gjeldum, N.; Celent, L. From Industry 4.0 towards Industry 5.0: A Review and Analysis of Paradigm Shift for the People, Organization and Technology. *Energies* **2022**, *15*, 5221. [CrossRef]
42. Bonekamp, L.; Sure, M. Consequences of Industry 4.0 on Human Labour and Work Organisation. *J. Bus. Media Psychol.* **2015**, *6*, 33–40.
43. Maresova, P.; Soukal, I.; Svobodova, L.; Hedvicakova, M.; Javanmardi, E.; Selamat, A.; Krejcar, O. Consequences of Industry 4.0 in Business and Economics. *Economies* **2018**, *6*, 46. [CrossRef]
44. Mian, S.H.; Salah, B.; Ameen, W.; Moiduddin, K.; Alkhalefah, H. Adapting Universities for Sustainability Education in Industry 4.0: Channel of Challenges and Opportunities. *Sustainability* **2020**, *12*, 6100. [CrossRef]
45. Goel, P.M.; Kumar, P.; Johri, P.; Srivastava, S.K.; Suhag, S. A Comparative Study of Industry 4.0 with Education 4.0. In Proceedings of the 4th International Conference: Innovative Advancement in Engineering & Technology (IAET), Jaipur, India, 21–22 February 2020; p. 3553215. [CrossRef]
46. Tan, S.Y.; Hussain, A.; Mustafina, J.; Aljaaf, A.J.; Alloghani, M. A Perspective on Education to Support Industry 4.0: A Qualitative Case Study in UK. In Proceedings of the 2019 12th International Conference on Developments in eSystems Engineering (DeSE), Kazan, Russia, 7–10 October 2019; pp. 215–220.
47. Wiśniewska-Salek, A. Education, Competences-Labor Market Analysis against the Challenges of Industry 4.0 Economy. *Syst. Safety Hum.-Tech. Facil.-Environ.* **2020**, *2*, 142–149. [CrossRef]
48. Wiśniewska-Sałek, A. Knowledge Management—Education in the Light of Industry 4.0. *Syst. Safety Hum.-Tech. Facil.-Environ.* **2019**, *1*, 969–977. [CrossRef]
49. Paschek, D.; Mocan, A.; Draghici, A. Industry 5.0–The expected impact of next industrial revolution. In *Thriving on Future Education, Industry, Business, and Society, Proceedings of the MakeLearn and TIIM International Conference, Piran, Slovenia, 15–17 May 2019*; ToKnowPress: Celje, Slovenia, 2019.
50. Kuper, H. Industry 4.0: Changes in work organization and qualification requirements—Challenges for academic and vocational education. *Entrep. Educ.* **2020**, *3*, 119–131. [CrossRef]
51. Pereira, A.G.; Lima, T.M.; Charrua-Santos, F. Industry 4.0 and Society 5.0: Opportunities and Threats. *Int. J. Recent Technol. Eng.* **2020**, *8*, 3305–3308. [CrossRef]
52. Pfeiffer, S. *Effects of Industry 4.0 on Vocational Education and Training*; ITA Manuscript 15-04; Institut für Technikfolgen-Abschätzung: Vienna, Austria, 2016. [CrossRef]
53. Sudibjo, N.; Idawati, L.; Harsanti, H.R. Characteristics of Learning in The Era of Industry 4.0 and Society 5.0. 2019, pp. 276–278. Available online: https://www.atlantis-press.com/proceedings/icoet-19/125925095 (accessed on 17 July 2023).
54. Banciu, F.V.; Feier, A.I. Aspects regarding skills and education related to Industry 4.0. In *MATEC Web of Conferences 2021*; EDP Sciences: Les Ulis, France, 2021; Volume 343, p. 11014. [CrossRef]
55. Ujakpa, M.M.; Osakwe, J.O.; Iyawa, G.E.; Hashiyana, V.; Mutalya, A.N. Industry 4.0: University Students' Perception, Awareness and Preparedness—A Case of Namibia. In Proceedings of the 2020 IST-Africa Conference (IST-Africa), Kampala, Uganda, 18–22 May 2020; pp. 1–10.
56. Matúšová, S.; Kollár, V. Labour and Education Markets in Industry 4.0. *Acta Educ. Gen.* **2023**, *13*, 1–25. [CrossRef]
57. Vetiska, J.; Holub, M.; Blecha, P.; Bradac, F.; Brazina, J.; Stanek, V.; Kroupa, J.; Tuma, Z. Industry 4.0 in Educational Process. In *Digital Conversion on the Way to Industry 4.0*; Durakbasa, N.M., Gençyılmaz, M.G., Eds.; Springer International Publishing: New York, NY, USA, 2021; pp. 324–332. [CrossRef]

58. Anackovski, F.; Kostov, M.; Pasic, R.; Kuzmanov, I. The Impact of Industry 4.0 on Education and Future Jobs. In Proceedings of the 2021 56th International Scientific Conference on Information, Communication and Energy Systems and Technologies (ICEST), Sozopol, Bulgaria, 16–18 June 2021; pp. 185–188.
59. Vikhman, V.V. Technological trends of Industry 4.0 in education: Opportunity navigator. *Prof. Educ. Mod. World* **2022**, *12*, 29–36. [CrossRef]
60. Teknowijoyo, F. Relevansi Industri 4.0 dan Society 5.0 Terhadap Pendidikan Di Indonesia. *Educatio* **2022**, *16*, 173–184. [CrossRef]
61. Barzotto, M. Industry 4.0 and Educational Strategies. *Acad. Manag. Proc.* **2018**, *2018*, 17–21. [CrossRef]
62. Sackey, S.M.; Bester, A. Industrial engineering curriculum in industry 4.0 in a South African context. *S. Afr. J. Ind. Eng.* **2016**, *27*, 101–114. [CrossRef]
63. Krdžalić, A.; Hodžić, L. Sustainable engineering challenges towards Industry 4.0: A comprehensive review. *Sustain. Eng. Innov.* **2019**, *1*, 1–23. [CrossRef]
64. Azerbaijan National Academy of Sciences; Institute of Information Technology; Aghayev, F.; Mammadova, G.; Azerbaijan National Academy of Sciences; Institute of Information Technology; Melikova, R.; Azerbaijan National Academy of Sciences; Institute of Information Technology. Trends and prospects for IT education in Industry 4.0. *Probl. Inf. Soc.* **2022**, *13*, 97–103. [CrossRef]
65. Flynn, J.; Dance, S.; Schaefer, D. Industry 4.0 and its Potential Impact on Employment Demographics in the UK. *Adv. Transdiscipl. Eng.* **2017**, *6*, 239–244.
66. Yakimov, P.I.; Asparuhova, K.K.; Grigorova, T.G.; Shehova, D.A. Industry 4.0 and the Challenges Faced by STEM Education. In Proceedings of the 2020 XXIX International Scientific Conference Electronics (ET), Sozopol, Bulgaria, 16–18 September 2020; pp. 1–4.
67. Cavas, B. Industry 4.0 and Science Education. *J. Balt. Sci. Educ.* **2019**, *18*, 652–653. Available online: https://www.ceeol.com/search/article-detail?id=948652 (accessed on 9 May 2023). [CrossRef]
68. Cézanne, C.; Lorenz, E.; Saglietto, L. Exploring the economic and social impacts of Industry 4.0. *Rev. D'économie Ind.* **2020**, *169*, 11–35. [CrossRef]
69. Stachová, K.; Papula, J.; Stacho, Z.; Kohnová, L. External Partnerships in Employee Education and Development as the Key to Facing Industry 4.0 Challenges. *Sustainability* **2019**, *11*, 345. [CrossRef]
70. Chou, C.M.; Shen, C.H.; Hsiao, H.C.; Shen, T.C. Industry 4.0 Manpower and Its Teaching Connotation in Technical and Vocational Education: Adjust 107 Curriculum Reform. *IJPES* **2018**, *5*, 9–14. Available online: https://dergipark.org.tr/en/pub/pes/issue/57198/807690 (accessed on 12 May 2023). [CrossRef]
71. Rericha, T.; Navratil, J.; Steiner, F.; Tupa, J. Educational methods for Industry 4.0. In Proceedings of the 2022 International Conference on Diagnostics in Electrical Engineering (Diagnostika), Parkhotel Pilsen, Czech Republic, 6–8 September 2022; pp. 1–4.
72. Spöttl, G.; Windelband, L. The 4th industrial revolution—Its impact on vocational skills. *J. Educ. Work.* **2020**, *34*, 29–52. [CrossRef]
73. Keser, H.; Semerci, A. Technology Trends, Education 4.0 and Beyond. *Contemp. Educ. Res. J.* **2019**, *9*, 39–49. [CrossRef]
74. University 4.0: The Industry 4.0 paradigm applied to Education—Université de Pau et des Pays de l'Adour. Available online: https://hal-univ-pau.archives-ouvertes.fr/hal-02957371/ (accessed on 12 May 2023).
75. Rao, S.K.; Prasad, R. Impact of 5G Technologies on Industry 4.0. *Wirel. Pers. Commun.* **2018**, *100*, 145–159. [CrossRef]
76. Cevik Onar, S.; Ustundag, A.; Kadaifci, Ç.; Oztaysi, B. The Changing Role of Engineering Education in Industry 4.0 Era. In *Industry 4.0: Managing The Digital Transformation*; Ustundag, A., Cevikcan, E., Eds.; Springer International Publishing: New York, NY, USA, 2018; pp. 137–151. [CrossRef]
77. Bordel Sánchez, B.; Alcarria Garrido, R.P.; Robles Valladares, T.E. Industry 4.0 Paradigm on Teaching and Learning Engineering. *Int. J. Eng. Educ.* **2019**, *35*, 4. Available online: https://www.ijee.ie/contents/c350419.html (accessed on 5 November 2023).
78. Education in the Era of Industry 4.0: Qualifications, Challenges, and Opportunities: Business & Management Book Chapter | IGI Global. Available online: https://www.igi-global.com/chapter/education-in-the-era-of-industry-40/276894 (accessed on 12 May 2023).
79. Loy, J.; Novak, J.I. The Future of Product Design Education Industry 4.0. In *Research Anthology on Cross-Industry Challenges of Industry 4.0*; IGI Global: Hershey, PA, USA, 2021; pp. 1666–1685. [CrossRef]
80. Moreira, F.; Ferreira, M.J.; Seruca, I. Digital transformation—A new challenge for higher education: A curriculum proposal. In Proceedings of the 10th Annual International Conference of Education, Research and Innovation, Sevilla, Spain, 16–18 November 2017; pp. 8124–8131.
81. Grodek-Szostak, Z.; Siguencia, L.O.; Szelag-Sikora, A.; Marzano, G. The Impact of Industry 4.0 on the Labor Market. In Proceedings of the 2020 61st International Scientific Conference on Information Technology and Management Science of Riga Technical University (ITMS), Riga, Latvia, 15–16 October 2020; pp. 1–5.
82. Hernández-Muñoz, G.M.; Habib-Mireles, L.; García-Castillo, F.A.; Montemayor-Ibarra, F. Industry 4.0 and Engineering Education: An Analysis of Nine Technological Pillars Inclusion in Higher Educational Curriculum. In *Best Practices in Manufacturing Processes: Experiences from Latin America*; García Alcaraz, J.L., Rivera Cadavid, L., González-Ramírez, R.G., Leal Jamil, G., Chong Chong, M.G., Eds.; Springer International Publishing: New York, NY, USA, 2019; pp. 525–543. [CrossRef]
83. Doyle-Kent, M.; Kopacek, P. Industry 5.0: Is the Manufacturing Industry on the Cusp of a New Revolution? In Proceedings of the International Conference on Production Research, Vienna, Austria, 25–30 August 2019; Springer International Publishing: New York, NY, USA, 2019; pp. 432–441.

84. Javaid, M.; Haleem, A. Critical Components of Industry 5.0 towards a Successful Adoption in the Field of Manufacturing. *J. Ind. Integr. Manag.* **2020**, *05*, 327–348. [CrossRef]
85. Alvarez-Aros, E.L.; Bernal-Torres, C.A. Technological competitiveness and emerging technologies in industry 4.0 and industry 5.0. *An. Acad. Bras. Ciências* **2021**, *93*, e20191290. [CrossRef] [PubMed]
86. Zhang, C.; Chen, Y.; Chen, H.; Chong, D. Industry 4.0 and its Implementation: A Review. *Inf. Syst. Front.* **2021**, 1–11. [CrossRef]
87. Kamsi, N.S.; Firdaus, R.B.R.; Razak, F.D.A.; Siregar, M.R. Realizing Industry 4.0 Through STEM Education: But Why STEM Is Not Preferred? In *IOP Conference Series: Materials Science and Engineering*; IOP Publishing: Bristol, UK, 2019; Volume 506, p. 012005. [CrossRef]
88. Nair, M.M.; Tyagi, A.K.; Sreenath, N. The Future with Industry 4.0 at the Core of Society 5.0: Open Issues, Future Opportunities and Challenges. In Proceedings of the 2021 International Conference on Computer Communication and Informatics (ICCCI), Coimbatore, India, 27–29 January 2021; pp. 1–7.
89. Haeffner, M.; Panuwatwanich, K. Perceived Impacts of Industry 4.0 on Manufacturing Industry and Its Workforce: Case of Germany. In *8th International Conference on Engineering, Project, and Product Management (EPPM 2017)*; Şahin, S., Ed.; Springer International Publishing: New York, NY, USA, 2018; pp. 199–208. [CrossRef]