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Review

Exploring the Adoption of Robotics in Teaching and Learning in Higher Education Institutions

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Abstract: Artificial intelligence (AI) has become a prevalent part of many businesses, including higher education. AI is progressively gaining traction as an instrumental engagement tool in higher education institutions (HEIs). The premise underlying this trend is the potential of robots to foster enhanced student engagement and, consequently, elevate academic performance. Considering this development, HEI's must probe deeper into the possible adoption of robotics in educational practices. This paper aims to conduct a comprehensive exploration into the adoption of robotics in teaching and learning in the higher education space. To provide a holistic perspective, this study poses three questions: what factors influence robotics uptake in HEIs, how can robots be integrated to improve teaching and learning in HEIs, and what are the perceived benefits of robotics implementation in teaching and learning. A bibliometric analysis and comprehensive review methodology were employed in this study to provide an in-depth assessment of the development, significance, and implications of robotics in HEIs. The dual approach offers a robust evaluation of robotics as a pivotal element needed for the enhancement of teaching and learning practices. The study's findings uncover the increasing adoption of robotics within the higher education sphere. It also identifies the challenges encountered during adoption, ranging from technical hurdles to educational adjustments. Furthermore, this paper offers guidelines for various stakeholders for the effective integration of robotics into higher education.

Keywords: artificial intelligence; adoption; robotics; teaching and learning; higher education institutions

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1. Introduction

Artificial intelligence (AI) has become a prevalent part of today's society. In this regard, it has remarkably transformed and revolutionized processes and practices of many businesses and organizations including higher education [1]. For instance, it has transformed the health sector by improving patient care, medical research, diagnosis, and therapy. In the field of transportation, artificial intelligence (AI) algorithms can examine real-time traffic data from sensors, cameras, and other sources to forecast traffic patterns, pinpoint congested areas, and improve signal timings [1–3]. Higher education institutions (HEIs) recognize the transformative potential AI holds in enhancing the way content is delivered.

In this study, we focus on specific applications of AI and robotics in higher education. AI in education refers to intelligent software systems capable of performing tasks that typically require human intelligence, such as visual perception, speech recognition, decision-making, and language translation. On the other hand, robotics in education refers to the use of programmable machines that can carry out actions autonomously or semi-autonomously, often used for hands-on learning experiences.

AI has indeed played a transformative role in both robotics and education. In robotics, AI technologies have enabled robots to perform complex tasks, learn from their environment, and adapt to different situations [4]. In education, AI has facilitated personalized learning, virtual classrooms, and automated grading systems, enhancing the learning experience for students worldwide. The integration of AI in these fields continues to bring about significant advancements. By leveraging robotics technology, higher education institutions can provide immersive and interactive learning experiences, enabling students to engage with concepts in a hands-on and dynamic manner [5,6]. This technological integration offers a range of potential benefits and transformative possibilities [7] and also provides personalized and adaptive learning experiences tailored to individual student needs [8].

Numerous literature reviews and bibliometric analyses have delved into the integration of robotics within higher education institutions (HEIs). Eguchi et al. and Mubin et al. [9,10] investigated the influence of educational robots on student engagement, learning outcomes, and skill development. Feil-Seifer et al. [11] explored the role of assistive robots in enhancing accessibility for students with disabilities. Additionally, Kim et al. [12] analyzed how robotics fosters interdisciplinary collaboration across fields such as computer science and engineering. Collectively, these studies highlight the significant benefits of integrating robotics in HEIs, including enhanced learning experiences, improved skill development, robust research support, and increased operational efficiency. Specifically, the deployment of robots in administrative roles can substantially reduce staff workload, enabling educators and administrators to focus on more complex and strategic tasks. Moreover, the adoption of robotics in higher education is increasingly seen as essential for future readiness and innovation. By incorporating robotic technologies, HEIs can better prepare students for the evolving demands of the modern workforce, promote cutting-edge research, and streamline institutional operations. Therefore, the integration of robotics in higher education is not only advantageous but also crucial for fostering an innovative and inclusive academic environment.

As robotics continues to evolve, higher education institutions have a unique opportunity to embrace this transformative technology and revolutionize the way knowledge is imparted. Considering this development, HEIS must delve deeper into the possible adoption of robotics in educational spaces. Thus, this paper aims to conduct a comprehensive exploration into the adoption of robotics in teaching and learning in the higher education space. To provide a holistic perspective, this study poses three questions:

- What factors influence robotics uptake in HEIs?
- How can robots be integrated to improve teaching and learning in higher education institutions?
- To what extent is robotics implementation perceived to be beneficial to HEIs?

2. Literature Review

This section provides an overview of research related to the topic under investigation. Several researchers are reporting on the utilization of various interventions and approaches in teaching and learning programming such as robotics [13]. According to [14,15], these interventions and approaches have evidenced positive impacts on the student's understanding and motivation. Nevertheless, this paper will only focus on exploring the adoption of robotics in teaching and learning in higher education institutions.

A study conducted by [15], on "the effectiveness and impact of robotic activities introduced into a regular higher education computer science curriculum in a developing country", reveals that the use of robot-based activities in the education sector has led to an increase in the number of students who attended the laboratory sessions and improved students' understanding of the programming concepts. The analysis of this study, however, reveals certain drawbacks associated with robotics in education. Firstly, students in this study perceived robots as limited to laboratory settings, restricting their ability to practice coding skills outside of the designated laboratory environment. This raises questions regarding why robots are confined to a specific location and whether they could be made accessible in other areas, such as libraries. Providing broader access to robots could enable students to engage with robotics and coding skills beyond the confines of specialized laboratories, promoting a more inclusive and versatile learning experience. Secondly, power outages pose a significant challenge, as robots are dependent on a continuous power supply to function, meaning that students cannot progress with their laboratory work during power outages.

A comparable investigation conducted by [16] suggests that the use of educational robotics to teach computer science in Africa highlights the important impact of robotics education in advancing computer science learning and nurturing technological proficiency. Particularly for previously disadvantaged students, it helps bridge the digital divide by exposing them to modern technology and empowering them with essential skills for the 21st century. However, the integration of educational robotics into the existing curriculum requires adjustments. This study highlights that integrating robots into the curriculum poses challenges, including aligning activities with learning objectives, providing educator training, managing time constraints, addressing resource limitations, ensuring equitable student access, adapting the curriculum, developing appropriate assessments, navigating technological advancements, promoting interdisciplinary collaboration, and overcoming resistance to change. A comprehensive and strategic approach is essential for successful integration [17]. Another challenge identified in the study is the presence of infrastructure limitations, such as unreliable electricity supply, and a lack of access to computers or robotics kits. These constraints impede the effective implementation of educational robotics programs, making it challenging for students to fully engage with the technology.

Considering the challenges identified in implementing robotics in education, it is crucial to gradually introduce the focus of the paper: exploring the adoption of robotics in teaching and learning within higher education institutions. The subsequent sections will address these identified gaps by providing a comprehensive analysis of the challenges, thus proposing strategies to overcome them [4]. By examining the current state of robotics integration in higher education, analyzing existing research and best practices, and conducting case studies, this study aims to offer valuable insights and practical recommendations for successfully incorporating robotics into teaching and learning environments, especially in higher education. The ultimate objective is to bridge these gaps and optimize the educational experience through the effective utilization of robotics technology.

The literature indicates that the implementation of robotics in higher education institutions (HEIs) is widely regarded as highly beneficial, as supported by the findings of various studies on robotics in education [18]. This review affirms that robotics is a valuable element that enhances educational environments by seamlessly integrating technology [19,20]. The extent to which these perceived benefits contribute to the overall educational landscape is a central question explored in this study. Researchers echo sentiments supporting the benefits of using robots for educational purposes, emphasizing their role in enabling students to grasp programming concepts effectively and engage in meaningful learning experiences [15,21]. This collective body of research underscores the positive impact of robotics on education, emphasizing its potential to foster improved learning outcomes for students. The interdisciplinary nature of robotics, as perceived in HEIs, not only promotes collaboration and critical thinking but also aligns education with industry trends, preparing students for success in technology-driven fields [22]. Overall, the integration of robotics in HEIs is considered instrumental in cultivating essential skills and enhancing the educational experience for students. These studies collectively emphasize the positive impact of robotics on education and its potential to foster improved learning outcomes for students.

However, as the incorporation of robotics into higher education gains momentum, certain challenges and considerations emerge. One of the central concerns revolves around striking the right balance between the role of robots and human instructors. While robots can undoubtedly offer unique advantages such as consistent delivery of content and personalized learning experiences, it is crucial to ensure that these technological tools do not overshadow the importance of human guidance and mentorship [6]. Additionally, ethical and societal dimensions come into play. The potential privacy implications associated with the data collected during interactions with educational robots raise concerns about how this information is stored, used, and protected [23,24]. Furthermore, the question of AI biases and the equitable distribution of access to robotic-enhanced education need careful attention to prevent exacerbating existing inequalities.

3. Method for Bibliometrics

A comprehensive literature review was conducted, with bibliometrics established as the research methodology to meet the objectives of this study. This methodology quantifies and evaluates scientific documents in detail. The study uses a keyword-based search in an international online bibliographic database, namely, the Web of Science.

This chosen research methodology is suitable due to its comprehensive coverage, citation analysis and bibliometric study capabilities, advanced search features, reputation for quality-controlled content, relevance to multidisciplinary research, provision of historical data, and ease of export and citation management. The review's eligibility criteria were established as follows, determining which papers would be suitable for inclusion in the analysis.

- Inclusion Criteria 1: papers associated with the topic concepts: artificial intelligence, adoption, robotics, teaching and learning, and higher education institutions.
- Inclusion Criteria 2: papers that are conference proceedings and articles.
- Inclusion Criteria 3: papers written in English.
- Inclusion Criteria 4: papers delimiting the concept of AI and robotics.
- And exclusion criteria consisted of the following:
- Exclusion Criteria 1: papers that did not feature any of the concepts: artificial intelligence, adoption, robotics, teaching and learning, and higher education institutions.
- Exclusion Criteria 2: papers that were retracted or book chapters.
- Exclusion Criteria 3: papers were written in any language other than English.

In the context of our study, book chapters were not considered mainly because they belong to a different theme and were not in alignment with the study's concepts. Thus, the exclusion of book chapters, retracted articles, and editorial notes is rooted in the recognition that these sources typically undergo less stringent peer-review processes, exhibit diverse reporting methodologies, and may pose challenges in terms of accessibility. Additionally, the adopted methodological choice is driven by the overarching goal of upholding the study's quality standards and ensuring a more streamlined and consistent process for the comparison and extraction of information [24].

The PRISMA shown in Figure 1 illustrates the number of papers and records retrieved using the identified keywords during the search. Initially, the search yielded a total of 8776 documents, which included irrelevant papers and book chapters. After applying the exclusion criteria mentioned above, the study ultimately included 4241 documents, spanning the years 2011 to 2023. This rigorous selection process ensured the relevance and quality of the included literature.

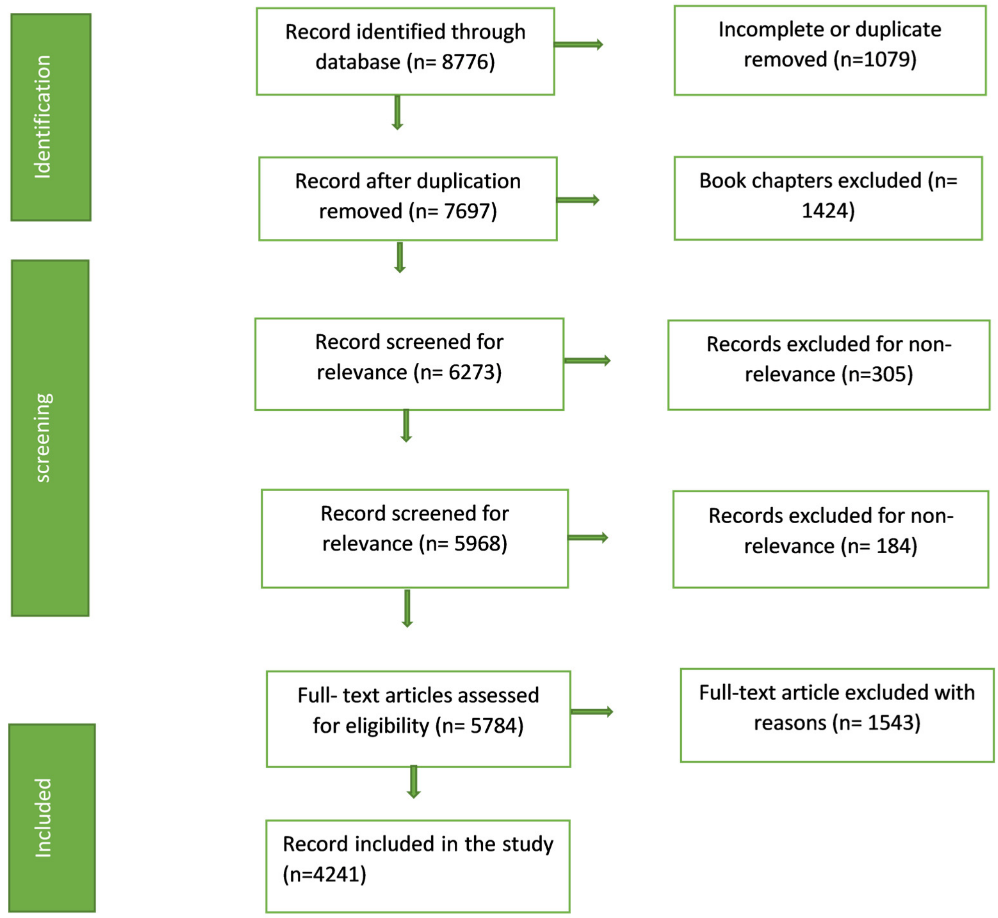

Figure 1. PRISMA flow chart.

4. Results and Discussion

The global adoption of artificial intelligence (AI) has been fueled by its potential to revolutionize various sectors, leading to increased productivity, innovation, and competitive advantages. Despite the growing prominence of AI concepts such as robots and robotics, some sectors, notably in educational spaces, particularly in Africa, still lag in their adoption. Consequently, there is a pressing need for further research to supplement and facilitate the integration of these technologies within the educational domain. This study aims to leverage existing knowledge to drive and enhance the adoption of robotics in education. To achieve this, the research employs a comprehensive and bibliometric analysis method to investigate the incorporation of robotics into the educational processes of higher education institutions. The study encompasses all documents related to the intersection of robotics and education within the years 2011 to 2023, as documented in the Web of Science database.

Figure 2 below illustrates the relationship between key themes—robotics in education and algorithms—and the study of this intersection. Examination of keywords reveals three distinct clusters: structural aspects, algorithms, and pedagogical inquiry. These clusters offer a comprehensive perspective on the multifaceted dimensions shaping the progress of robotics in education over almost a decade, aiding researchers in comprehending global advancements and identifying future directions.

The study of robotics in education involves the interplay between three intertwined themes: structural aspects, algorithms, and pedagogical inquiries. Structural aspects, which encompass the physical design and interaction capabilities of robots, directly influence their ability to engage with learners and the learning environment. Algorithms, consisting of instructions guiding a robot's behavior and interactions, are central to educational tasks performed by robots, shaping learning outcomes and experiences. Similar sentiments are echoed by the authors of [25] in their bibliometric analysis of specific energy consumption (SEC) in machining operations, which supports the notion that robots enhance teaching and learning, ensuring alignment with educational objectives and instructional strategies for improved student learning experiences.

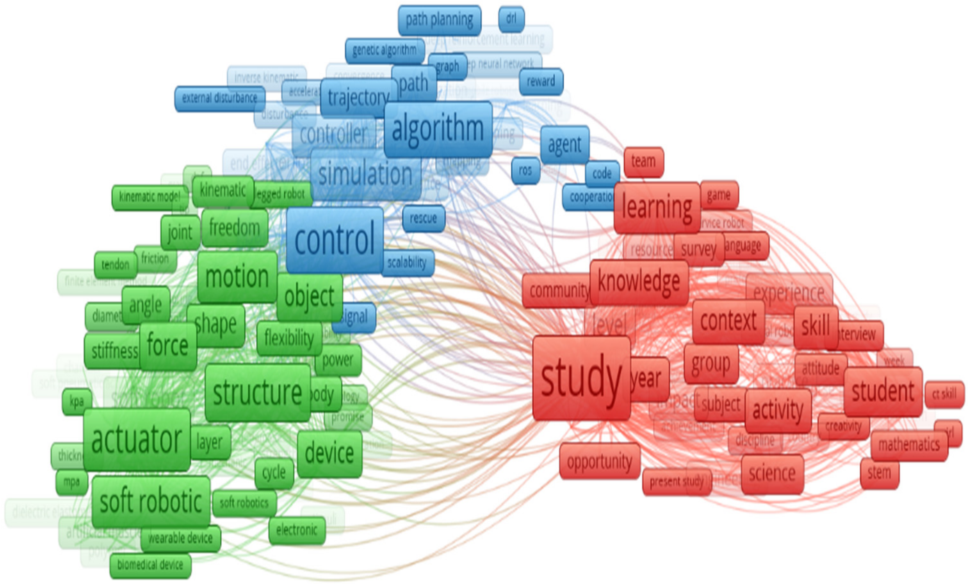

Figure 2. Relationship between themes.

Additionally, existing research underscores the pivotal role of algorithms in guiding a robot's behavior and interactions. For example, Abbas et al. and Channa et al. [26,27] highlight the central significance of programming and instructional algorithms in shaping educational tasks performed by robots. Furthermore, this emphasis on pedagogical inquiry aligns with broader trends in the literature. The authors of [28] explore the importance of understanding how robots can enhance teaching and learning, emphasizing alignment with educational objectives and instructional strategies. Together, these studies contribute to a comprehensive discussion on the multifaceted dimensions shaping the progress of robotics in education, emphasizing the critical relationship between structural aspects, algorithms, and pedagogical inquiries.

The illustration in Figure 3 depicts the countries that have published research papers on the subject of robot education. Among these countries, a total of 8776 papers have been published. The study findings indicate that the United States has taken the lead in paper publication, with China following closely behind. Additionally, Germany, Italy, and England have all contributed a similar number of publications. The Web of Science data highlight Egypt and Algeria from Africa as front runners with 40 research papers, while South Africa has contributed 19 papers focusing on the intersection of robotics and education. This can lead to valuable insights, innovation, and potentially beneficial applications of robotics in educational contexts in these regions. It is important to recognize and celebrate research efforts from a variety of countries as they contribute to the global understanding of this important topic.

Numerous scholarly investigations have emphasized the United States' preeminent status in the realm of paper publication, given the substantial number of research articles that originate from this nation. These results continually highlight how the United States leads the world in producing research, with the conclusion that the United States has a major influence on the discourse and distribution of knowledge surrounding our research issue supported by the body of research as a whole.

The author of [29] provides further support for this viewpoint, affirming China's escalating publication output, notably in domains such as robotics and education. Their research highlights China's strategic aim to become a leader in artificial intelligence (AI) by 2030, as outlined in the 'New Generation Artificial Intelligence Development Plan' released by China's State Council in July 2017. The analysis of publication trends in the fields of robotics and education reveals a significant upsurge compared to previous years. This indicates a substantial increase in research activity related to robotics and education, potentially influenced by evolving trends and heightened interest in advancing these areas. Researchers are actively involved in studies aimed at improving the development, production, and application of robotics in education, demonstrating a growing dedication to enhancing educational technology and learning methodologies. This dual perspective presents a comprehensive view of the global landscape, with the United States and China emerging as key players in shaping research and development in our field of interest.

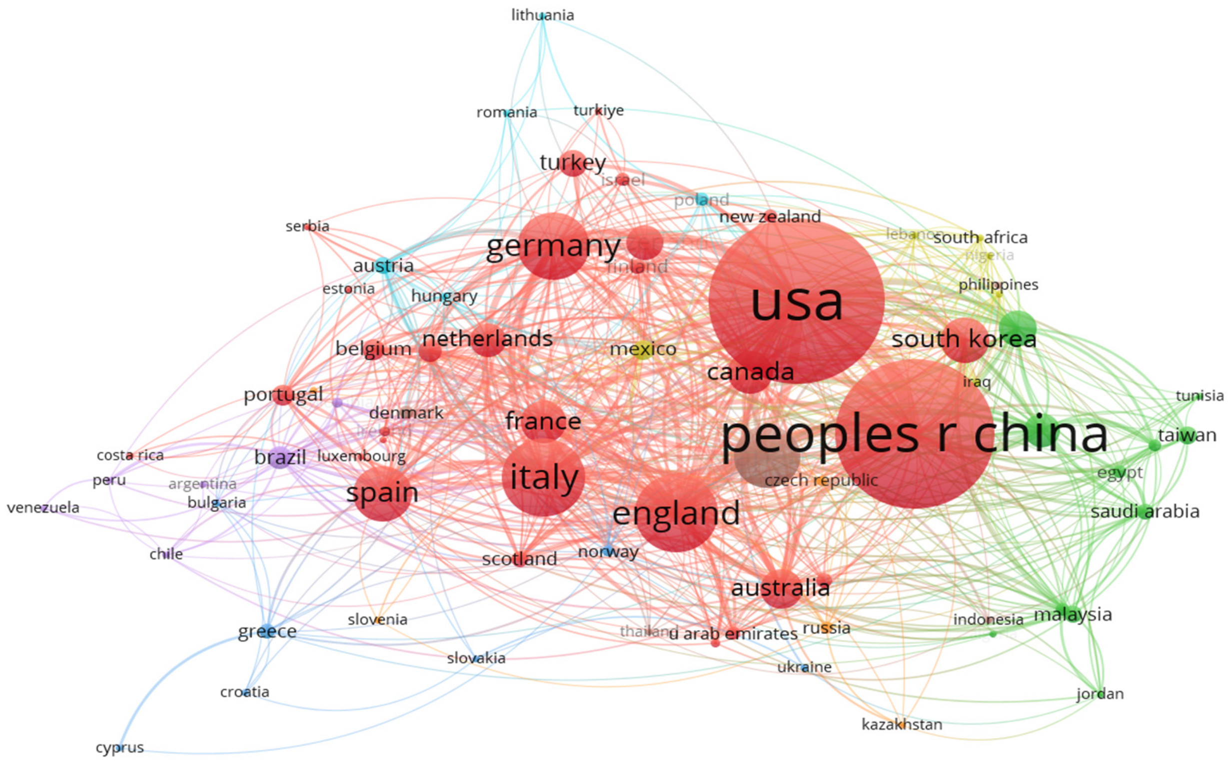

Figure 3. Countries that have published research papers on robots and education.

While African countries' research production is improving, the comparatively low quantity of research articles in comparison to other areas is cause for concern. This raises issues about the reasons for the gap and whether African countries have completely embraced and integrated robotics education. The poor research output from African countries can be attributed to a variety of causes, including resource restrictions, restricted access to technology, and divergent educational priorities. Addressing these issues and increasing the acceptability and implementation of robotics education could be critical in driving research activity and boosting innovation in African educational contexts (Figure 4).

A search was conducted on the Web of Science using the keywords "robot" and "education" spanning the years 2011 to 2023. This initial search resulted in the identification of 8909 papers. To refine the selection, book chapters were excluded, resulting in a reduced count of 4241 documents. These documents originate from 180 sources and display a growth rate of 5.34% per year in publications. The provided dashboard also indicates 11,796 authors associated with these documents, which have been referenced a total of 120,793 times. The frequency of citations indicates the level of interest in this area of research, showcasing the ongoing development and current focal points within this field. By examining the content of highly cited papers, insights can be gained concerning the influential research themes within the field being studied.

Figure 4. Main information on the document (4241).

Figure 5 provides a visual representation of a three-part diagram within the domain of robotics and education research. The diagram's purpose is to depict the interrelationships between keywords and their respective distributions. Within the diagram, rectangular shapes are employed to symbolize distinct components: keywords on the left, countries in the middle, and keywords plus on the right.

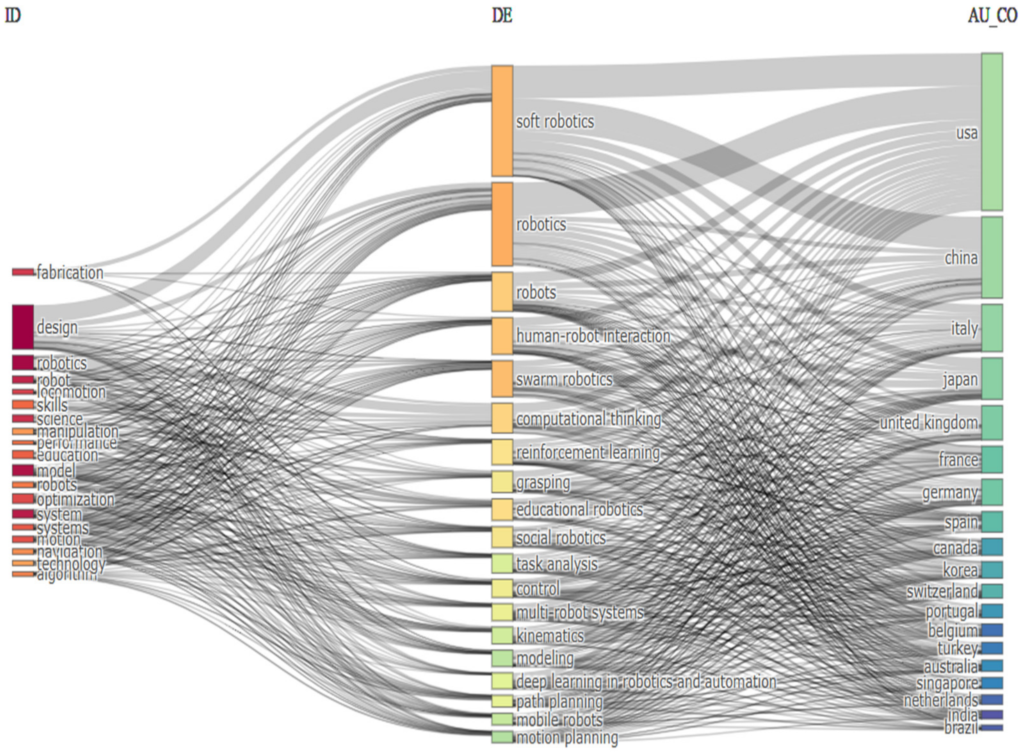

Figure 5. Three-field plot with the keyword and keyword plus distribution across the top leading countries in robotics.

Through a comprehensive analysis, certain patterns emerge. Notably, the United States, China, and Italy stand out as the primary contributors to research on soft robotics, robotics, robots, and human–robot interaction. This prominence is reflected in the relative heights of the rectangles associated with these countries. Furthermore, a detailed investigation of the US reveals a concentration of studies centered around robots, educational robotics, and computational thinking. These studies are closely linked to the keyword "designs", which contributes to the significant representation of the US in the diagram. Additionally, the keyword "robot" receives noteworthy attention in both US and Chinese research endeavors. This attention translates into research outcomes related to robotic education, swarm robotics, and grasping, as evidenced by the keyword plus distribution.

Through extensive literature scrutiny, multiple authors corroborate the recognition of the United States and China as pivotal contributors to research in soft robotics, robotics, robots, and human–robot interaction. The findings from [30] assert a dominant presence of American researchers, emphasizing the United States' role in advancing robotics technologies. Similarly, Zhong et al. [31] highlights China's increasing prominence, attributing its contributions to strategic initiatives and sustained investment in robotics research. These leading nations have demonstrated their leadership in the advancement of these technologies through the implementation of extensive research programs, consistent funding, and strategic initiatives. These countries frequently have well-established educational systems that include technology into the curriculum from an early age, such as computer use in elementary school. Moreover, the authors of [25] collectively affirm the influential contributions of Italy alongside the United States and China. This consistent observation across multiple studies strengthens the consensus that these three nations play a central role in shaping research and development within the field of robotics and human–robot interaction.

However, despite large contributions from the United States, China, and Italy, the concentration of research output from these countries raises concerns about the global community's representation in contemporary robotics research efforts. The prominence of these countries in the debate may overshadow contributions from other locations, thus limiting the diversity of perspectives and ideas in robotics and education research. As a result, there is a need to ensure greater representation and integration of research efforts from a wide range of countries and areas in order to create a more thorough understanding of robotics technologies and their applications in educational contexts around the world.

Figure 6 displays the frequency of certain words used in research related to robotics and education. For example, regarding the key word robots, this word occurred 127 times, and the high frequency of the word "robots" indicates that it is a central focus in research on robotics and education. This observation aligns with the findings of [25], which also emphasized the pivotal role of robots in shaping modern educational landscapes. Followed by the word system (134 times), The presence of "systems" suggests a focus on the design and implementation of complex robotic systems. Then, the frequency of use of the keyword robotics in the literature (226 times) demonstrates that the broader field of robotics, beyond just the robots themselves, is a significant area of investigation. The high frequency of use of "design" (645 times) indicates a substantial interest in the conceptualization and creation of robotic systems for educational purposes. This could involve designing robots with specific features to enhance learning experiences or optimizing the design of educational scenarios involving robots.

This convergence of views strengthens the evidence for the pivotal role of robotics in education. The identified trends in word frequencies, supported by the works of various researchers in the field, including [25], highlight the need for further exploration into specific areas. This collective body of research provides valuable insights for educators, researchers, and policymakers, offering a foundation for shaping the future of robotics in education and advancing pedagogical practices.

The illustration in Figure 7 depicts a word cloud that serves as a visual representation capturing the assortment of robotic concepts associated with different educational themes, as pertains to the author-defined keywords. The arrangement of this cloud is thoughtfully crafted, showcasing more prominently sized fonts for words of heightened importance or recurrent usage, while gradually diminishing font size for words with lower frequencies. Predominant terms frequently encountered within the abstract include "robots", "soft robots", and "robotics". This analysis highlights the noticeable repetition of terms shared between the abstract and the title. Notably, an interesting observation emerges: the terms "swarm robotics" and "human–robot interaction" are employed more extensively within the abstract compared to their utilization in the title and author's keywords. Additionally, the prominence of terms like "education robotics", "grasping", and "computer thinking" underscores the primary focus of the research on integrating robotics within educational contexts. The word cloud also indicates evolving trends and areas of growing interest within the field. This visualization not only identifies key terms but also provides insights into the thematic emphasis and research priorities, offering a comprehensive overview of the current landscape of robotics in education research.

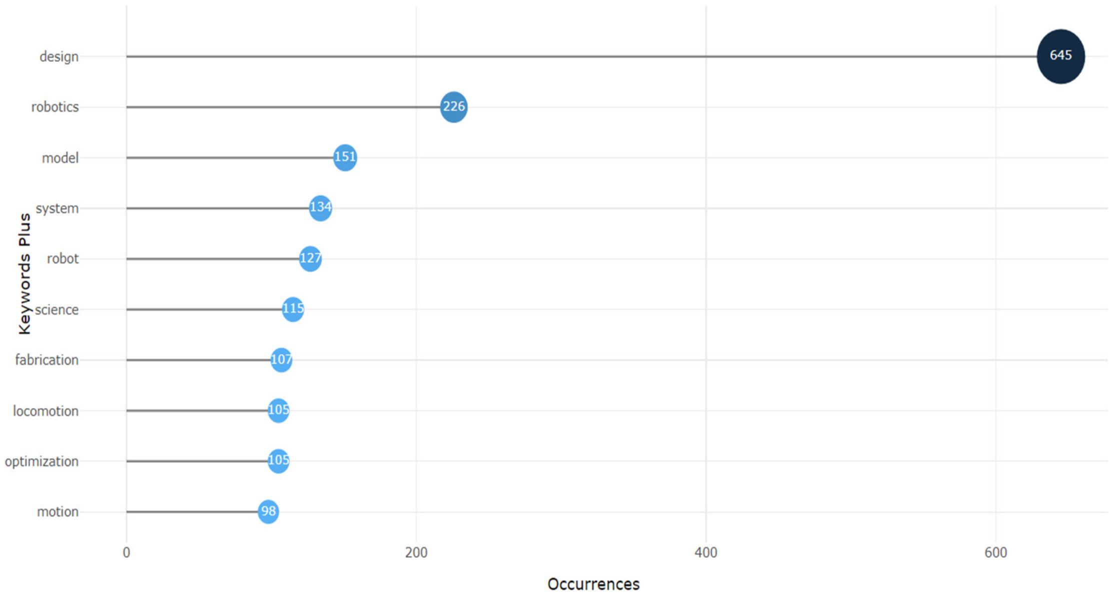

Figure 6. Most frequent words.

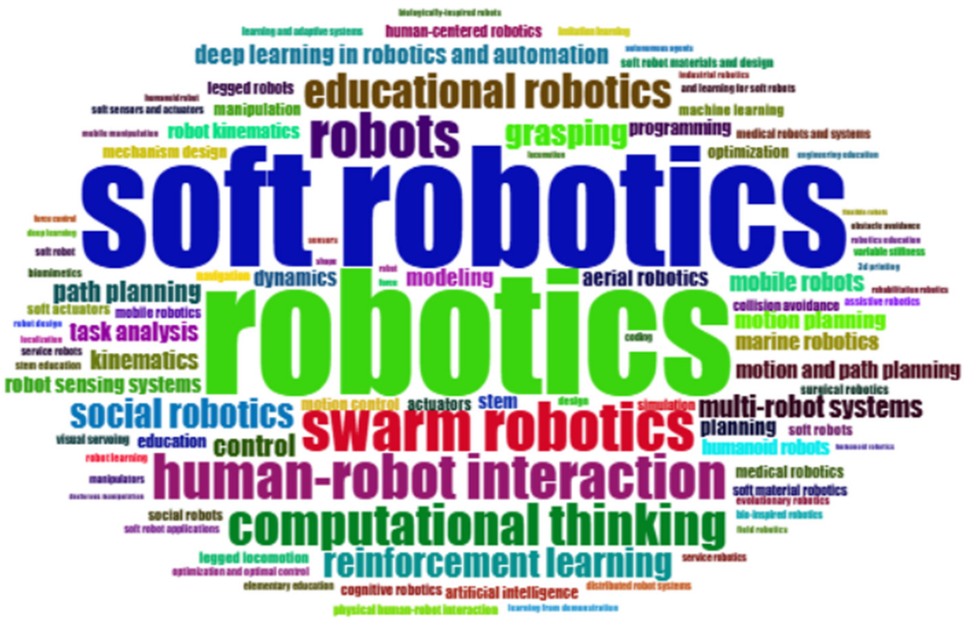

Figure 7. Word cloud based on the abstract square root presentation.

The literature review indicates a growing interest in using robots as supplementary tools to enrich education and enhance students' motivation and academic performance. Robotics have taken on a special interest in today's education, and the number of educational programs introducing this aspect into their curriculum has grown throughout the years, especially in developed countries [8,22,32–34]. This trend aligns with the broader integration of technology in the education sector, where various technological tools and applications are being adopted to support and improve learning experiences. As the development of educational robots continues and their integration into classrooms advances, researchers emphasize the importance of striking a balance between human and robotic interactions. This balance ensures that students receive a comprehensive education that combines the benefits of both technology and human involvement [35].

The review highlights challenges in integrating robots into education, including privacy and data security issues, ethical considerations, and potentially reduced human interaction. Privacy concerns arise from the need to store student data, which could be vulnerable to breaches. Ethical considerations involve ensuring equitable access to robotic resources for all students. Additionally, reliance on robots may reduce the human elements of teaching, affecting the development of soft skills and emotional intelligence. Addressing these challenges requires careful policy-making and a balanced approach.

Ethical and societal considerations, such as data privacy, security, potential biases in AI algorithms, and equitable access to technology, are crucial when integrating robots into education. Several factors enable HEIs to integrate robotics into their curriculum effectively. Identified factors driving and influencing the integration of robotics in HEIs include but are not limited to advancements in technology, availability of funding and resources, institutional commitment to innovation, collaboration with industry partners, curriculum development, faculty expertise and training, student interest and engagement, and regulatory and ethical considerations. Among these, the key factors particularly impacting developing countries are the following:

Factor 1: Advancements in technology—developing countries lack the availability of cutting-edge technology due to limited access to the latest innovations and infrastructure, which hinders the adoption and integration of robotics in HEIs.

Solution: encouraging local innovation and the development of homegrown solutions can also bridge the technological gap.

Factor 2: Funding and resources—limited budgets for educational institutions often mean that investing in expensive robotic technology is challenging.

Solution: HEIs should seek funding from international organizations, non-profits, and private sector partnerships dedicated to educational and technological advancement. Also, the governments should prioritize budget allocations for technology in education and create grant programs specifically for robotics integration.

Factor 3: Collaboration with industry partners—In developing countries, the lack of established relationships between HEIs and the robotics industry can impede progress.

Solution: HEI's to develop a string relationship with industry, find out what is expected of industry from HEIs through formal agreements, internships, joint research projects, and industry advisory boards. Governments can incentivize industries to collaborate with HEIs by providing tax breaks or other benefits.

Factor 4: Curriculum development—the existing curricula in many developing countries may not include robotics or related subjects, leading to a gap in the necessary knowledge and skills among students and educators.

Solution: collaborate with international educational institutions to adopt best practices and integrate relevant content into the local curriculum and also find a curriculum that covers topics that the students will encounter when they are out of school.

Factor 5: Faculty Expertise and Training: there is often a shortage of faculty members who are skilled in robotics and capable of teaching and conducting research in this field; this gap slows down the adoption and effective use of robotics in education.

Solution: HEIs should develop faculty development programs to train existing educators and staff members in robotics and establish collaborations with other universities to provide faculty exchange programs and access to specialized training.

These solutions address the barriers to integrating robotics in HEIs in developing countries, facilitating the effective adoption and utilization of robotic technologies in education. Nevertheless, the growing focus on incorporating robotics into teaching and learning (T&L) in recent years reflects a noteworthy trend in HEIs [2,30]. A thorough literature review underscores the diverse integration of robotics across different disciplines and contexts within HEIs [28]. While not as widespread as observed in primary and secondary education, the use of robotics is gaining momentum in higher education settings, particularly in fields such as engineering, computer science, robotics, automation, and related disciplines, where it is prominently featured as an educational tool. In alignment with this trend, institutions are introducing robotics to improve teaching and learning by providing students with hands-on experiences that bridge theoretical knowledge and practical applications [15]. This approach is designed to enhance the learning process, offering students a dynamic and engaging educational experience. By integrating robotics into higher education, institutions aim to equip students with skills directly applicable to the evolving demands of the job market, fostering interdisciplinary collaboration, enabling real-world applications, developing programming skills, promoting critical thinking, facilitating online and remote learning, increasing engagement, encouraging industry collaboration, creating inclusive learning environments, and offering research opportunities across various fields [36]. These offerings benefit HEIs as robotics provides a hands-on, interactive approach that makes learning more engaging and effective. Robotics helps students gain in-demand skills such as programming, problem-solving, and critical thinking. It encourages collaboration across different fields, integrating knowledge from engineering, computer science, and more. Robotics also assists HEIs in partnering with industries for research projects, internships, and funding, creating a bridge between academia and industry [37]. Additionally, integrating robotics into HEIs opens numerous research avenues, allowing students and faculty to explore innovative solutions and advancements in technology.

The above-noted trend is driven by the need to prepare students for the evolving job market and advancements in robotics technology. Kashive et al. and Kubilinskiene et al. [32,38] underscores the significance of robotics education in HEIs, emphasizing its role in cultivating interdisciplinary skills for success in the robotics and automation industries. This integration aims to foster research, innovation, and the ability to address societal challenges related to robotics technology [23,39]. However, the effectiveness of robotics education in preparing students for the dynamic field is influenced by key factors, comprising funding, curriculum design, industry collaboration, faculty training, and infrastructure readiness. These factors must be taken into consideration when implementing robotics in HEIs.

5. Implications of the Findings

Based on the findings and literature presented, several key factors influencing the incorporation of robotics in higher education institutions (HEIs) were identified, including funding, curriculum design, industry relationships, faculty training, and infrastructure preparedness, addressing solutions related to the identified key factors. Addressing these factors is crucial for the successful integration of robotics into classrooms, as they directly impact the effectiveness and sustainability of adoption. Successful integration of robotics into classrooms requires careful consideration of these variables to ensure effective adoption. The literature on integrating robotics to enhance teaching and learning in HEIs covers a broad range of topics. These include exploring pedagogical approaches that leverage robots for increased student engagement and understanding, aligning with educational goals, providing adequate training for educators, efficiently allocating resources, promoting equitable access for students, customizing curricula, developing assessments, navigating technological advancements, and addressing resistance to change. Studies consistently suggest that integrating robots can significantly enhance teaching and learning experiences in HEIs. Robots facilitate personalized learning, interactive exercises, and automation, creating dynamic classroom environments. They also contribute to skill development among students and support continuous professional development for teachers, thereby preparing students for future challenges. Moreover, various studies have identified multiple benefits associated with the integration of robotics in HEIs. These benefits include enhanced learning experiences, development of technical skills, readiness for the future workforce, research opportunities, global competitiveness, and alignment with technological trends.

However, it is essential to maintain a balanced perspective that considers both the advantages and challenges. While the advantages include improved student engagement and skill development, the challenges encompass the high costs of robotic technologies and potential barriers to adoption, such as resistance from faculty and students and the need for substantial infrastructure investment. A holistic approach that addresses these challenges and promotes sustainable adoption is critical for maximizing the benefits of robotics in HEIs. Therefore, the integration of robotics in higher education is not only advantageous but also crucial for fostering an innovative and inclusive academic environment. By incorporating robotic technologies, HEIs can better prepare students for the evolving demands of the modern workforce, promote cutting-edge research, and streamline institutional operations. This comprehensive approach ensures that the integration of robotics contributes to the overall advancement of higher education.

6. Conclusions

This study emphasizes a global interest in using robotics for education, with a notable gap between developed and African countries, as evidenced by the research conducted in [19,32]. In higher education institutions (HEIs), the adoption of robotics faces challenges influenced by economic factors, infrastructure readiness, and educational policies. Particularly in Africa, there is a need for focused research and initiatives to facilitate the integration of robotics into teaching and learning. The potential benefits of robotics in HEIs, including personalized learning experiences and addressing teacher shortages, are significant. However, a cautious and context-specific approach is essential, considering ethical concerns and ensuring equal access to robotics resources. The literature analysis reveals significant disparities in the adoption of AI and robotics in higher education across different regions. For instance, while universities in the United States and China are leading in the implementation of AI-driven tutoring systems and advanced robotics labs, many African institutions are still in the early stages of introducing basic coding and robotics courses. This gap is particularly evident in fields such as medical education, where some Western universities use sophisticated robotic patient simulators, while many developing countries lack access to such technology. Therefore, this study underscores the pressing need for targeted efforts to bridge the gap in robotics adoption, especially in African HEIs. A comprehensive and ethical approach is crucial to unlock the substantial benefits robotics can bring to teaching and learning environments globally.

7. Limitations

In spite of its contributions, this study is limited to the Web of Science database, as one of the most important bibliographic databases. The papers included in the search were those associated with the topic concepts: artificial intelligence, adoption, robotics, teaching and learning, and higher education institutions. Moreover, the search was limited to conference proceedings and articles written in English. Future research should expand the database to include other significant sources such as Scopus or Google Scholar, and considering non-English publications could provide a more comprehensive overview of the field. Incorporating qualitative analysis alongside bibliometric methods could also offer richer, more nuanced insights into the research trends and methodologies in this area.

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