Cogent Business & Management

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/oabm20

Effectiveness of social robots as a tutoring and learning companion: a bibliometric analysis

Rashmi Yogesh Pai, Ankitha Shetty, Tantri Keerthi Dinesh, Adithya D. Shetty & Namrata Pillai

To cite this article: Rashmi Yogesh Pai, Ankitha Shetty, Tantri Keerthi Dinesh, Adithya D. Shetty & Namrata Pillai (2024) Effectiveness of social robots as a tutoring and learning companion: a bibliometric analysis, Cogent Business & Management, 11:1, 2299075, DOI: 10.1080/23311975.2023.2299075

To link to this article: https://doi.org/10.1080/23311975.2023.2299075

COGENT BUSINESS & MANAGEMENT
2024, VOL. 11, NO. 1, 2299075
https://doi.org/10.1080/23311975.2023.2299075

MANAGEMENT | REVIEW ARTICLE

OPEN ACCESS Check for updates

Effectiveness of social robots as a tutoring and learning companion: a bibliometric analysis

Rashmi Yogesh Pai, Ankitha Shetty, Tantri Keerthi Dinesh, Adithya D. Shetty and Namrata Pillai

Department of Commerce, Manipal Academy of Higher Education, Manipal, India

ABSTRACT

A long-term perspective on how technology will mature is needed whereby robotics and artificial intelligence (AI) have accomplished a consequential and remarkable impact by finding their way into mainstream higher education. Robots have already become an indispensable factor in society and possess high potency as a part of educational technology. Social robot education is limited to complementing the digital aptitude of students in the world of information, and the role of social robots is crucial in polishing students 'cognitive and social abilities. This study reviews the effectiveness of social robots in education, where we highlight the application of educational robots, surrounded by a blend of social robots and enactive didactics, which could lead to promising ideas for tutoring activities in education. It is empirically proven that social robots can assist with literature, science, or technology education. We synthesize the role of social robots in education and weigh their pros and cons by examining the impact of their appearance on robots' performance as tutors, tools, or peers in learning exercises. The current study is the first bibliometric analysis that reflects robots' impact in the education field as tutors and learning companions. A total of 288 articles were reviewed, and the data were extracted to construct an overview through bibliometrics. The outcome of this study paves the way for educational institutes to make informed and fruitful decisions on the applicability of robots, which can help them comprehend the learning styles of students and create knowledgeable and well-adjusted learners.

ARTICLE HISTORY
Received 22 December 2021
Revised 20 December 2023
Accepted 21 December 2023

KEYWORDS
Social robot; education; artificial intelligence; technology; tutor; learner; bibliometrics

REVIEWING EDITOR
Pablo Ruiz, Universidad de Castilla-La Mancha, Spain

SUBJECTS
Artificial Intelligence; Teaching Assistants; Education Studies; Teaching & Learning - Education; Theories of Learning

1. Introduction

The world of education has presently been undergoing a second revolution. Digital technologies such as mobile devices, computers, digital media creation, video games, and social networking sites are transforming the intellects of schooling and learning. Paperback books and educational technologies such as televisions inculcate a general proposition about the link between educational change and technology. Pupils are educating themselves with the aid of new technology (Belpaeme et al., 2018). With this new technological wave in education, students are engaging in online courses where different traditional education system practices are challenged by unique learning opportunities and niches (Smakman et al., 2021). The latest new technology introduced in schools is computer technology, a known panacea for the stumbling block in the learning process. A proper structure should be contemplated and overhauled in the present education system, which determines how a teacher teaches and how a student learns and responds (Collins & Halverson, 2010).

Education is the key to success in the future and traces a roadmap directly toward opportunities in life. A person's mind is illuminated with learning insights, thus creating a way of thinking that helps the

CONTACT Adithya D. Shetty adithyad.shetty@manipal.edu Department of Commerce, Manipal Academy of Higher Education, Manipal, India

Supplemental data for this article can be accessed online at https://doi.org/10.1080/23311975.2023.2299075.

students with an in-time plan. Education helps develop human personality and thoughts and alerts people about challenging life experiences. It is recommended that individuals build a special status in society by being aware of events that influence life decisions. The world is currently facing a 'Global Educational Crisis', as mentioned by the United Nations on 3rd March 2021. The COVID-19 pandemic, imprinted with social distancing, has affected every walk-in society, and education is no exception. To keep up with the educational requirements, educational institutions had to make quick changes according to the situation. The pandemic outbreak accomplished an unprecedented and extraordinary push toward online learning (Teräs et al., 2020). Educational innovations have sprouted in different areas and in numerous forms. Innovation can be channeled toward progress in most aspects of the educational system: curriculum, theory, practice, teaching and learning, technology, policy, institutions and administration, the culture of the institution, and teacher education. Making a positive impact on learning and learners is the ultimate goal in education, it contributes to the reflection of the student, parents, teacher, educational administrators, researchers, and policymakers on the need for their involvement and support.

Learning refers to 'studying cognitive processes taking place in the brain, identifying and developing abilities, skills, and competencies' (Backfisch et al., 2021). These include improving behavioral attitudes, motivation, dispositions, self-assessment, autonomy self-efficacy, communication, and learning productivity. Education is nourished by society and sustains the community. Technology has undoubtedly served as a driving force and a weapon of innovation in all domains of human activity (Sailer et al., 2021). The impact of technology on education depends on various factors, including economic factors, such as dwindling school budgets. And increasing student count in a classroom, with a growing demand for substantial personalization of curricula for pupils with variable needs related to technology which underpins the efforts of teachers and parents (Belpaeme et al., 2018).

The field of education has been using artificial intelligence in the development of deep learning technology. Innovations based on technological applications can improve teaching and learning where robots are gradually becoming an integral part of society by contributing both to lives at home and at school. The role of social robots is critical in the lives of children and teenagers, where they can be used for intellectual development. With the rapidly changing technological environment, it can be understood that robots can serve as add-ons to education (Mubin et al., 2013). They prove to be an assistance to education by providing extra support. These applications do not replace any human teaching staff or reduce human contact time but are supplementary to existing pedagogical structures (Baxter et al., 2015). Social robots have emerged as an innovative digital wave in technology that is increasingly implemented in the learning and educational landscape.

Young children are assisted with a typical approach that supplements the learning process. Social educational robotics (SER) are conscious effort toward assisting comprehension for students with regard to STEM concepts. STEM education can be viewed from 'an inclusive perspective to include education in the individual disciplines of STEM, i.e. Science, Technology, Engineering, and Mathematics, as well as interdisciplinary or cross-disciplinary combinations of respective STEM disciplines' (Lin et al., 2021). These robots are artificial technological generators intended to assist in daily activities in the domain of education, holding great potential and bringing moral challenges (Tolksdorf et al., 2021). Robots in education are becoming effective at recurrent tasks and delegating mundane chores so that most educators can focus most of their attention and time on educating pupils.

The wisdom behind a tutoring and learning companion scaffolds students' learning process, which is reflected in the current study. The tutor helps students remember vocabulary and adapt the arithmetic exercises based on the students' performance. The robot and the student collaboratively solve exercises that enable a robust platform for learning. The present bibliometric analysis helps to illuminate the effectiveness of robots in education, where they play a tutoring and learning companion role (Smakman et al., 2021).

We used bibliometric analysis to determine the effectiveness of engaging social robots in both learning and tutoring for the students' and teachers' daily lives. This study aims to provide a review of the effectiveness and scope of social robots in the field of education. It has been empirically proven that social robots can assist with literature, science, and technology education. Here, we synthesize the role of social robots in education, weigh their pros and cons, and examine the impact of their appearance on the outcome, shedding light on the role of robots as tutors, tools, or peers in learning exercises. To bridge this gap, the current study attempts to determine the magnitude of the effectiveness of social robots in education through a bibliometric analysis, which is the first study that reflects the impact of robots in education as tutors and learning companions.

2. Review of the literature

With the advancement of technology and its increasing role in education, the use of multimedia tools has increased with the involvement of social robots (Pachidis et al., 2019). Researchers opine that a few of the behavioral influences of social robots in education interpret different interactions between humans and robots. Hence, robots that do not try to exhibit social behavior could be incorporated as educational tools for teaching students about technology (Tang & Chu, 2022). Virtual agents attempt to persuade them to perceive a life-like social interaction partner that communicates through natural modalities such as gestures, speech, and emotional expressions, where the effect is enhanced by the physical robotic embodiment (Saerbeck et al., 2010). Social robots check students' and teachers' attitudes toward the involvement of technology in the classroom.

Robotic education falls within the domain of 'artificial intelligence tools', such as machines and deep learning in computational intelligence-based systems, redefining society economically and in various ways (Ramírez et al., 2020). A social robot enhances students' engagement and performance while they undertake tasks that require cognition. This study highlights that robots help with metacognitive strategies that effectively enhance learning and prove their effectiveness in the educational domain. The development of deep learning technology has paved the way for the application of artificial intelligence in education and gestures widely used by teachers in the teaching process (Lu et al., 2014). Robot tutors utilize certain methods and techniques and tailor the dexterity of problems to judge the capabilities of pupils and attempt to provide a series of learning styles (Smakman et al., 2021).

However, after checking students' and teachers' attitudes toward the involvement of technology in the classroom over the past few years, there has been increasing interest in students in the fields of technology, science, and mathematics (Kandlhofer & Steinbauer, 2016). An insufficient number of students make decisions to pursue the technical profession. With the advancement of technology and its increasing role in education, the use of multimedia tools has increased, as has the use of social robots (Pachidis et al., 2019).

Therefore, many countries, such as those in sub–Saharan Africa, and Central and East Asia, are already facing a lack of well-trained technicians, engineers, and researchers. In this case, robots are conscious of how to change the educational scenario (Share & Pender, 2018).

Children are found to be learning with robots even during playtime. Therefore, analysis and assessment of social robots have become crucial for determining the influence of robotics on children's cognitive, language, ethical, and social interactive skills. Research has shown that younger students like to work with robots and prefer a robot as their learning companion rather than a private tutor. A robot's ability to interact and vividly express its emotions has proven to be responsible for such a priority.

Over the years, education has been acting as an oracle with the influence of technology, particularly focusing on the impact of educational robots in several developing countries. It is usually developed countries that were seen to conduct elaborate research on the matter, hold seminars, and perform experiments to assess the rise or fall in productivity. The most popular offerings of robotic competitors in Europe are the First Legos, imported from the US Robo Cup Junior, which is the most prominent international robot competition for schools (Smakman et al. 2021). Robots are employed in education to learn robotics, such as sensors, actuators, and programming a robot (Saerbeck et al., 2010). Robots are already prevalent in the field of education.

Research studies have focused on understanding the different critical aspects of educational interactions for which the response of robots determines the behavior of social robots, which can affect learning outcomes (Ekström & Pareto, 2022).

LEGO Mindstorm is the most common and popular kit. They can teach various subjects, such as computer science, programming, robotics, and language. *Nao* is a humanoid robot, that is especially attractive to young people. It is used to teach real-time operations, such as treatment in education, to engross students with learning difficulties through a 'therapeutic process'. A number of languages for programming, including Java, C++, and Python, are provided. The *BeeBot* is a colorful bug-like robot. It is a social robot made especially for younger students to teach preliminary concepts of mathematics and programming. Along with being easy to use, it is also affordable. It can also be used to teach control and sequencing, directional and positional language, repetitions, and program sequences, with the understanding of algorithms. *Vex IQ* is used to execute traditional-style programming. *Romibo* is a service robot that requires remote control and possesses the ability to move, send gestures, and speak, and that tries to polish cognitive and educational skills.

Thymio, a tiny robot, enables students to learn robotic language. This robot is easy to program and affordable. *IROBI* is a commercial tutor that was released in the early 2000s. It was specifically structured and designed for teaching English, and it has proven to boost concentration and academic performance. Kaspar, which stands for kinesics and synchronization in personal assistant robotics, is a doll-like humanoid that helps parents and teachers of children with autism and other major communication difficulties. Kaspar has been intentionally structured with an expressive face cut, as autistic children have difficulty interpreting voice and reading expressions (Wainer et al., 2014).

Robots have proven to be an exciting way to master electronics, languages, computers, and mechanical engineering. Younger people achieved better results post-learning than did audio and books, and the former was found to be more effective when language learning was made feasible with a robot. These robots are a type of educational technology used to promote learning and improve academic performance in children (Mubin et al., 2013).

It is evident that the rapid development of technology has led to the use of multimedia tools in education, where the use of robots in schools is becoming more popular in the 21st century. According to Beran et al. (2011), 'Children are also playing more with technologically advanced devices during their playtime'. Studies were also conducted to determine the influence and impact of robots on language, cognition, communication, social networks, and interactions between school children. Research on robot application in education needs a systematic vision to elucidate a roadmap for future studies (Ekström & Pareto, 2022). Recognizing certain shortcomings, this study tries to emphasize the importance and utility of educational robots, illustrated with a blend of enactive didactics and social robotics, for various tutoring activities in an educational context. However, when analyzing whether robots can substitute for and replace human teachers, no study has indicated that robots are more efficient than humans are. The ultimate shortage of evidence supporting the merits of social robots should be seen as a golden opportunity for upcoming researchers.

A bibliometric analysis is necessary to gauge the overview of the impact of social robots in an educational context to underline the importance of teachers, tutors, parents, and other caregivers who are irreplaceable. Despite research studies on the positive impact of robots, few studies conclude that robots can act like people. On the other hand, several studies prove that children acknowledge and learn more from human tutors than from robot tutors (Kennedy et al., 2016). Bibliometrics is becoming a significant tool for grasping the universal perspective of a particular research domain with comprehensive delimitation. By exploring several features of academic articles, we can expose the pillars of knowledge in social robots as a taxonomy by creating maps of science or academic landscapes. The present bibliometric analysis tries to synthesize the role of social robots in education, weigh their pros and cons, and examine the impact of their appearance on the outcome, shedding light on the role of robots as tutors, peers or tools in learning exercises. This study is the first bibliometric analysis that reflects the impact of robots in the education field as tutors and as learning companions. This study identifies certain research trends pointing to studies on the use of robots as tutors and as learning companions.

3. Method

This study is the first bibliometric analysis that reflects the impact of robots in the education field as tutors and learning companions. A total of 288 articles were reviewed from SCOPUS, and the data were extracted to construct an overview through bibliometrics using the Biblioshiny tool. The analysis was performed with SCOPUS, a freely accessible web platform, with various publications in different scientific domains in the global distribution context. Given the need for a database representing the global scientific publication system, we used SCOPUS as a data source because of its disciplinary coverage (Van Eck & Waltman, 2019). For visualization techniques, tools exist for visualizing bibliometric networks, such as distance-based, graph-based, or time-based networks, through Biblioshiny. Biblioshiny encompasses an extravagant and extensive set of techniques that are palpable and well suited for practitioners to better load and export data efficiently (Moral-Muñoz et al., 2020). In this bibliometric analysis, we incorporated the 'graphic add-on biblioshiny' package for the 'bibliometrix' in R. Studio. Comprehensive science mapping was envisaged considering segmentation and fragmentation of the body of knowledge (Burda et al., 2020). The 'Biblioshiny' tool was developed by an Italian scholar named Massimo Aria in the R language environment. Biblioshiny is a flexible tool that tries to fulfill the data flow and extent of literature analysis, thus preventing research experts from performing multiple steps and tedious operations (Xie et al., 2020). This approach improves and enhances work efficacy, thereby reducing the intensity and possibility of errors. Biblioshiny is well suited for multistep computing tasks through which researchers rewrite the R language program code, which matches their requirements.

3.1. Concept map

Through an extensive study of the articles collected, the extracted data were analyzed with keywords such as 'Social Robots' AND 'Education' AND 'Artificial Intelligence' AND 'STEM education'. Furthermore, the search operators depicted the keyword search syntax for the bibliometric analysis (Table 1).

3.2. Research protocol

A search using the keyword search string 'Social Robots' AND 'Education' AND 'Artificial Intelligence' AND 'STEM education' identified 313 documents whose language was limited to English. The data extracted included articles, conference proceedings and chapters from 2010 to 2021. It is ideal to plan a bibliometric map for a period of 10 years or more for a better understanding of the overview. Additionally, social robots in education started gaining importance a decade ago when technology crept into the education sector. In the past 10 years, improvements in artificial intelligence and dexterity have been the result of advanced end-of-arm tooling for precise movements through robotics in education (Gittings, 2020). Of the 313 documents, N = 6 editorials, short surveys, and notes were excluded. Additionally, few studies (n = 8) were in other languages and were also excluded. After the abstract was screened, 11 documents did not match the study contents; hence, only N = 288 documents supported the bibliometric analysis (Figure 1).

These data were further subcategorized under the results and discussion. In addition, several diagrams and tables have been added to provide a better understanding of the findings. The results section consists of a three-field plot, thematic map, conceptual structure map, source growth, and word cloud. The articles used for this study were selected after detailed consideration of the needed objective was given, keeping in mind the focus of the study.

4. Results and analysis of findings

4.1. Three field plots

Figure 2 is a three-field plot that is an illustration comprising three components, consisting of a list of countries of origin, authors, and topics or keywords. These three components are represented by gray lines linking their relationships with each other, arriving from the country of origin, followed by the author. Every author is then connected to related keywords about the topic. The size and intensity of each rectangular block linking each component represent the number of articles related to the topic.

Table 1. Concept map.

Term 1	Term 2	Term 3	Term 4
Social Robots OR Educational Robots OR Child Robots OR Humanoid Robots OR Assistive Robots	Education OR Higher Education OR Early Children Education OR Elementary Education	Artificial intelligence OR Machine Learning OR Robotics learning	STEM Education OR Robotics Education

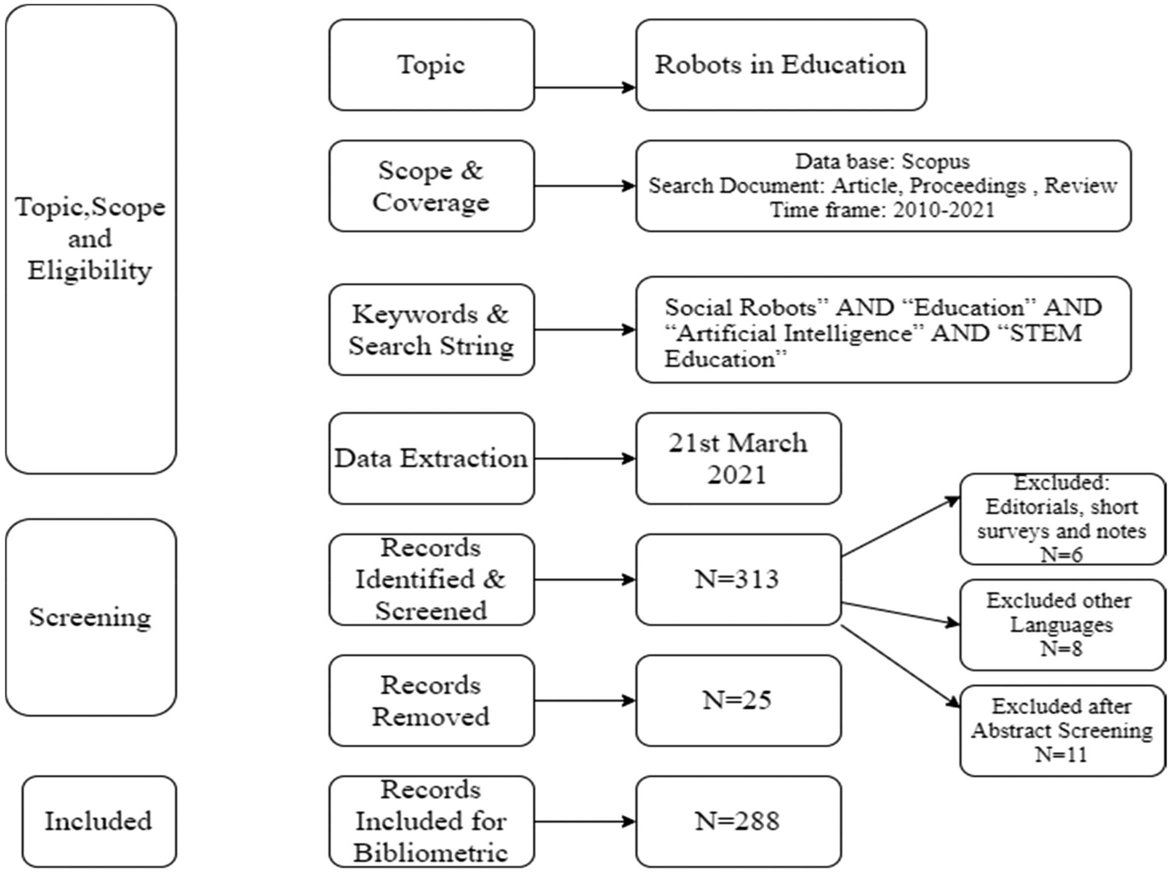

Figure 1. Research protocol.

The first component on the left lists the countries, the articles, and the journals in support of social robots in education. A total of eleven journals are tabulated in the three-field plot depicting the published articles on social robotics in education. Most related studies were conducted in Greece, where the results are denoted with an orange rectangle and linked to several other authors, namely, Kaburlasos VG, Vrochidou E, Lytridis C, Papakostas GA and Bazinas C. These studies revolved around the topics of autism, autism spectrum disorder, educational robots, social robotics, human robot interaction, and child robot interaction.

The second component in the middle contains the authors' names. The top 20 authors are listed in the indicated plot. The size of the rectangle represents the number of research articles written by the author. In this plot, Dillenbourg P, Kennedy J and Johal W had the largest rectangles, whereas Gordon G, Kaburlasos and Belpeame T had the same size rectangles.

The third element contains the keywords associated with the topic that appeared continuously in the articles. Each topic is related to the authors publishing the journal. Seventeen keyword topics are listed, and the most frequent keyword was 'CHILD-ROBOT INTERACTION', as demonstrated by the size of the mustard rectangle, followed by 'SOCIAL ROBOT', which altogether dominated the other rectangles. It also appeared that almost all the registered authors used the topics 'child robot interaction' and 'social robot'; these matches fit with the findings of related scientific research articles on social robots and interactions. In addition, this plot also portrays other keywords that have been used widely, such as 'human-robot interaction' and 'education'.

4.2. Word cloud

A 'word cloud' is a visual representation of the word frequency. Through the word cloud shown in Figure 3, one can envisage the words appearing very frequently in the articles on which analysis was performed. The word most used was 'SOCIAL ROBOT', followed by 'EDUCATION' and 'CHILD-ROBOT INTERACTION'. The

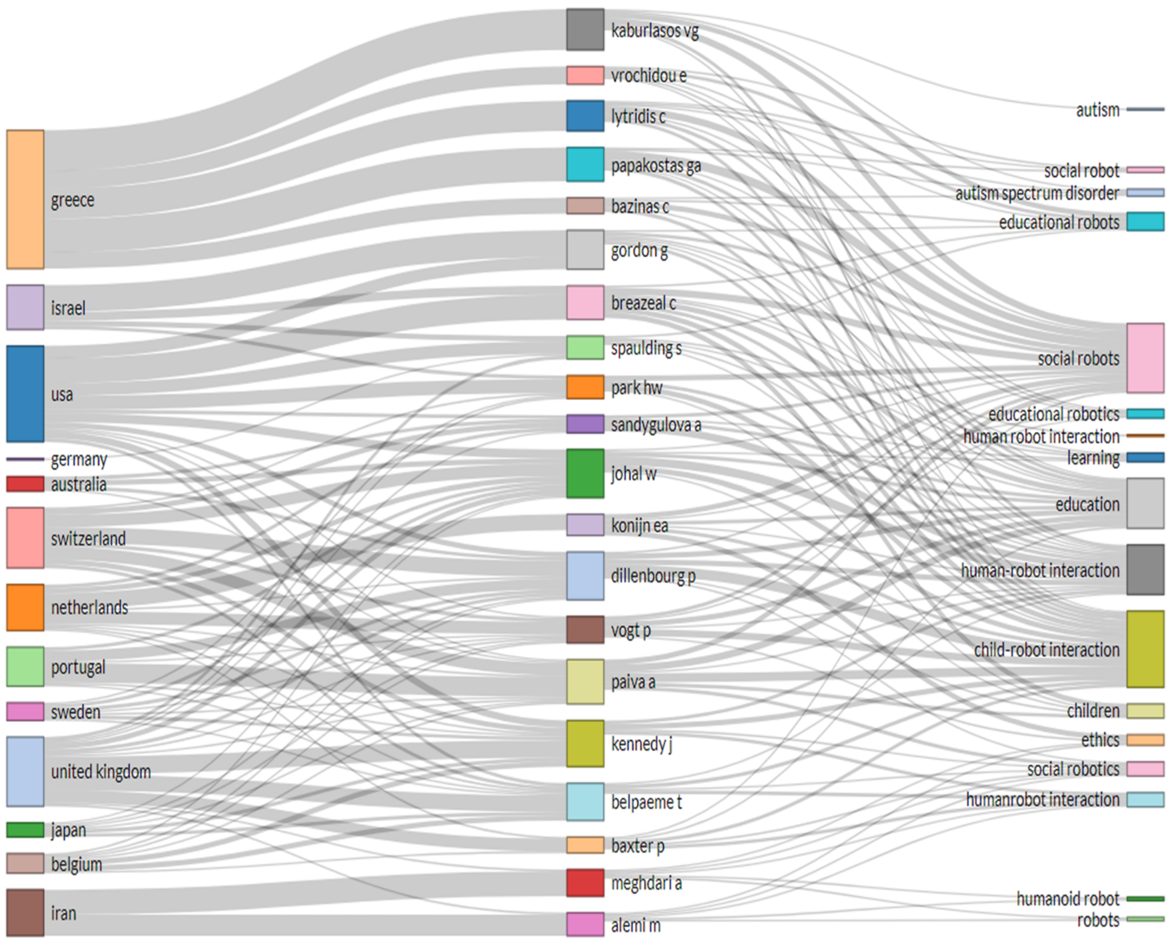

Figure 2. Three field plots.

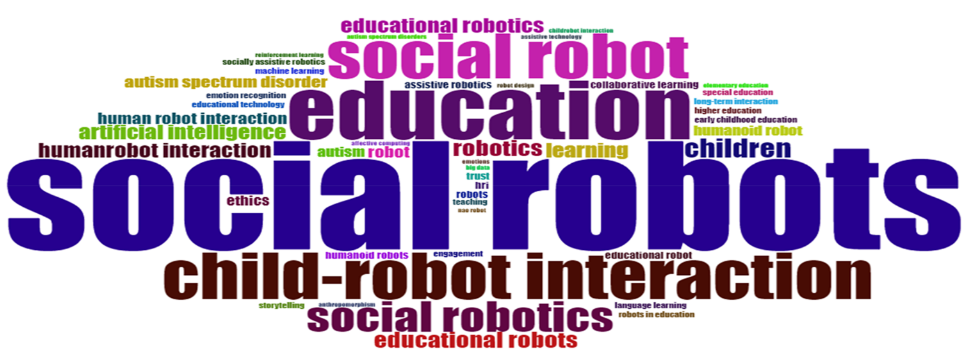

Figure 3. Word cloud.

more familiar words appear within the analysis depicting the same intensity, the more common words appear in the word cloud. Even though words are randomly placed, the most used words have been placed in the middle of larger font sizes to ensure visibility. Concerning this, the words 'social robot', 'education', and 'child robot interaction' were emphasized using a larger font compared to the rest. This shows the importance of the keywords with regard to the area of focus of the study. Among the articles that were evaluated for inclusion in this analysis, the related research revolved around these words. Other areas of focus include 'human-robot interaction', 'children', and 'autism spectrum disorder'. A word cloud is a visual tool for amplifying textual data. This approach is a simple way to communicate the most salient features of the research study. With the help of the word cloud given above, it can be noted that most of the existing research articles on the topic of social robots tend toward education and child robot interaction.

4.3. Co-occurrence map

This analysis outlines the connections between the categories of different keywords after considering denotations and pluralism. The co-occurrence network of different keywords is determined by the occurrences, co-occurrences, and associations of every keyword in published research articles on social robots and education. The title words used in the co-occurrence network analysis and the associations and nodes of the 50 most frequently used words in published articles on social robot studies are shown in the above figure.

Each node in the co-occurrence map signifies the utilized keywords, and the lines portray the co-occurrence or the number of times each title word appears. The size of each node signifies the strength of occurrence of the words used in the published article on social robots and education.

The construction of a co-occurrence network, as shown in Figure 4, enables the scouting and traversal of the conceptual structure of the educational research domain. The co-occurrence network posits that this research domain was divided into many clusters. The ones highlighted in red were devoted to a generalized notion of social robots predominantly connected to 'human–robot interaction', 'children', and 'autism spectrum disorder'. For the purpose of sound innovative research, the social robot cluster is evidenced to be of great significance and particular interest. The well-known fact that is noted is that the notions of 'social robots', 'educational robots', 'human-robot interaction', and 'children' are situated very close to one another, which contributes to their semantic similarity and proximity. The collective usage of these keywords provides us with a strong foundation and a robust background for administering an in-depth analysis of the studies through this stream of novel research.

4.4. Thematic map

Figure 5 is a thematic map that is based on centrality and density. It is categorized into four compartments. The outcome was retrieved from a partially automatic algorithm by considering the titles of all the references considered in this study and new relevant keywords to outline a more elaborate variety. The upper right quadrant shows 'robotics' or 'artificial intelligence' topics, highlighted by a high density and centrality, suggesting that the issues are to be prioritized during future studies. The top-left quadrant shows a distinct yet underrepresented topic variation that covers the scope of development,

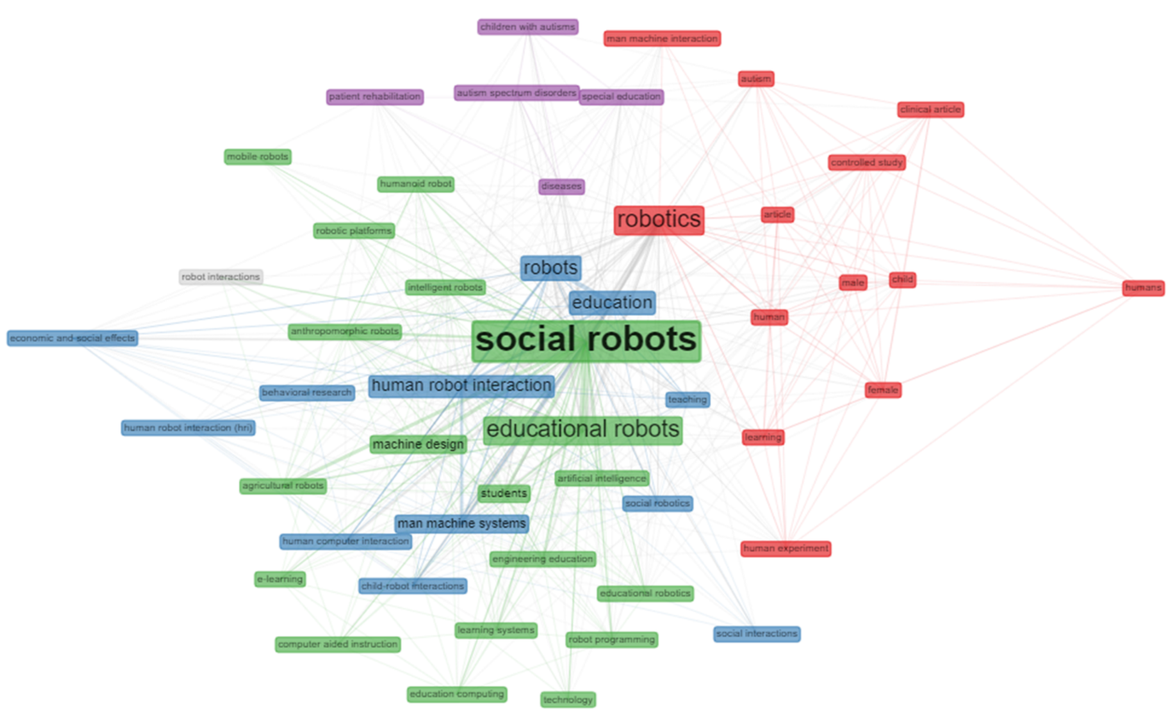

Figure 4. Co-occurrence map.

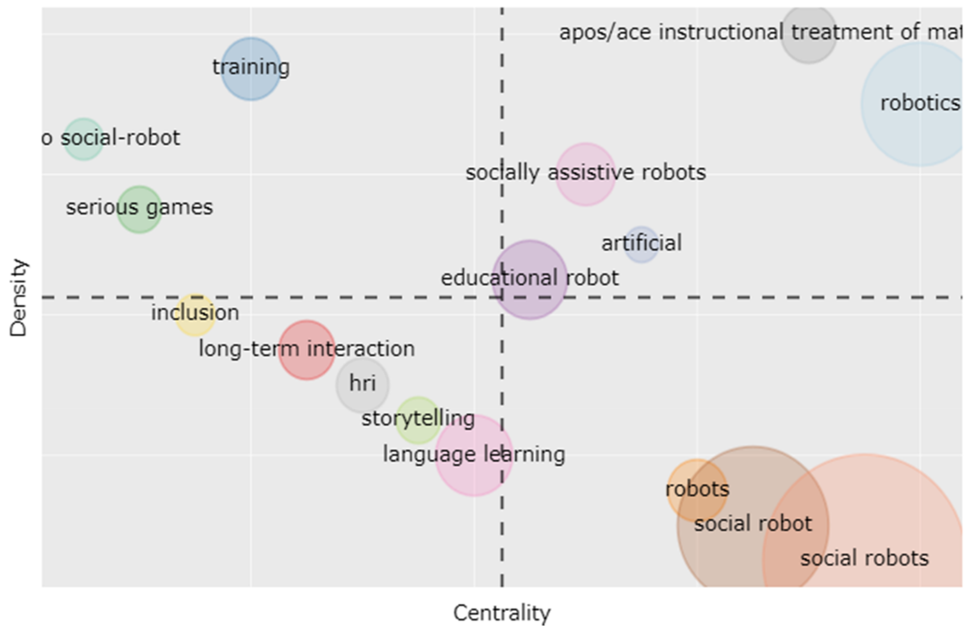

Figure 5. Thematic map.

nevertheless highlighted by high density but low centrality, including 'social robots', 'serious gaming', and 'training'. The quadrant at the lower left consists of topics that witnessed a downward trend despite being used quite often, determined by high centrality and density; this compartment included 'inclusion', 'long-term interaction', 'human-robot interaction', 'storytelling', and, to some extent, 'language learning'. Conclusively, the quadrant at the lower right consists of foundational topics determined by high centrality but low density; these topics are significant in research as general topics and encompass 'robots', 'social robots' and somewhat 'language learning'.

4.5. Conceptual structure map

Figure 6 shows the conceptual structure map, which visualizes the substantial structure of different keywords that often appear in research articles and journals on 'Social Robots in Education' through the process of regional mapping. Keywords are positioned according to Dim 1 and Dim 2, Dim being a diminutive particle creating a relation of words. The map shown below is divided into two parts: the blue and red areas containing words related to one another. The red area consists of a wider variety and number of words, which shows the relation between many research articles based on the words used. The words used most often are 'early childhood education', 'trust', 'robot', 'humanoid robot', 'child', 'language learning', 'child robot interaction', 'ethics', 'socially assistive robots', 'education', 'social robot', 'autism spectrum disorder', 'stem education', 'robot design', 'artificial intelligence', 'social performance', etc., are seen in the diminutive red particle. The words placed close to each other are closely related to each other and are mentioned in the articles together. The words located away from each other are less related to each other. The Dim 1 value is 55.23%, and the Dim 2 value is 13.68%, which produces a map between keywords whose values are not very different. The blue area shows high connectivity with 'human' and 'human' experiments.

4.6. Source growth

Figure 7 is a culmination of curves depicting a few of the journals and their growth or lack thereof during the period between 2010 and 2021. The 'International Conference on Human Robot Interaction' had no source growth from 2010 to 2013 but drastically increased in 2017, declined again in 2019, and then moderately increased in 2020 and 2021. The International Journal of Robotics saw a gradual increase from 2010 to 2015, a slight decrease from 2010 to 2017, and a drastic increase from 2017 to 2021. 'Advances in

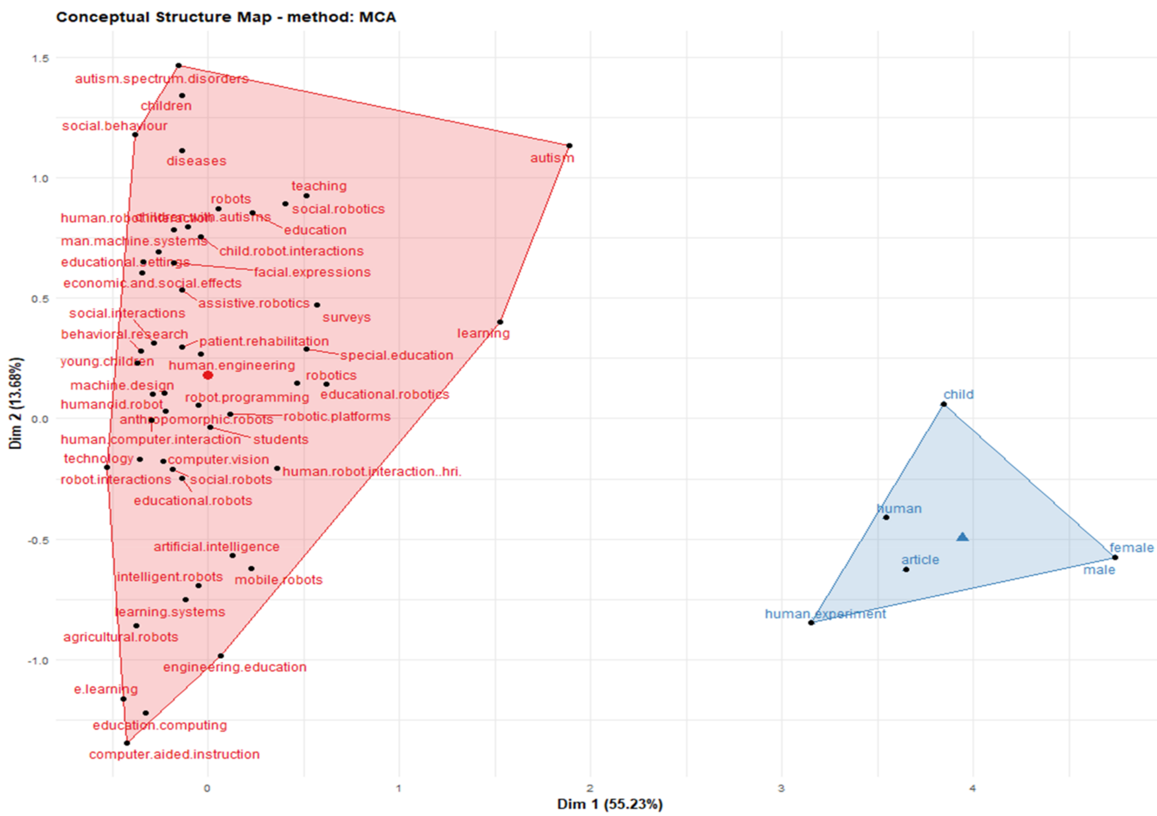

Figure 6. Conceptual structure map.

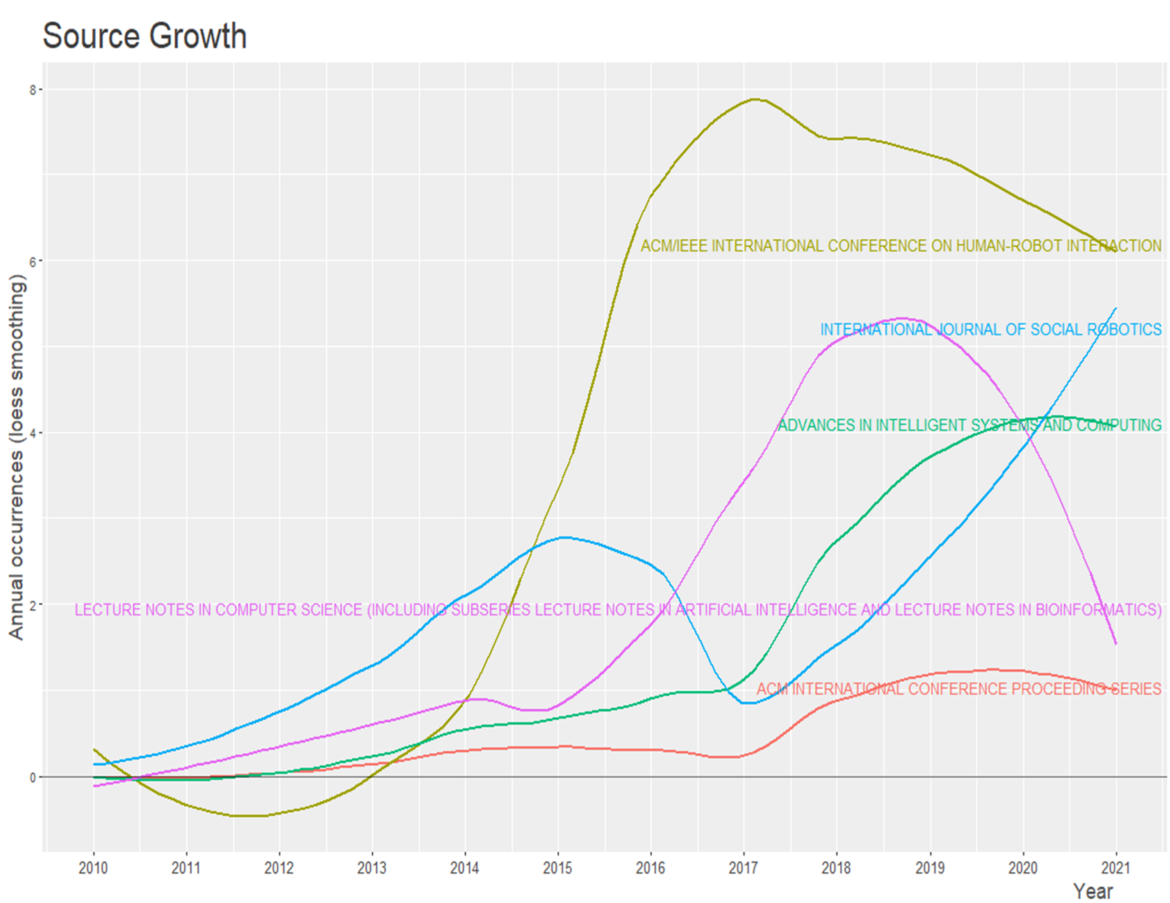

Figure 7. Source growth.

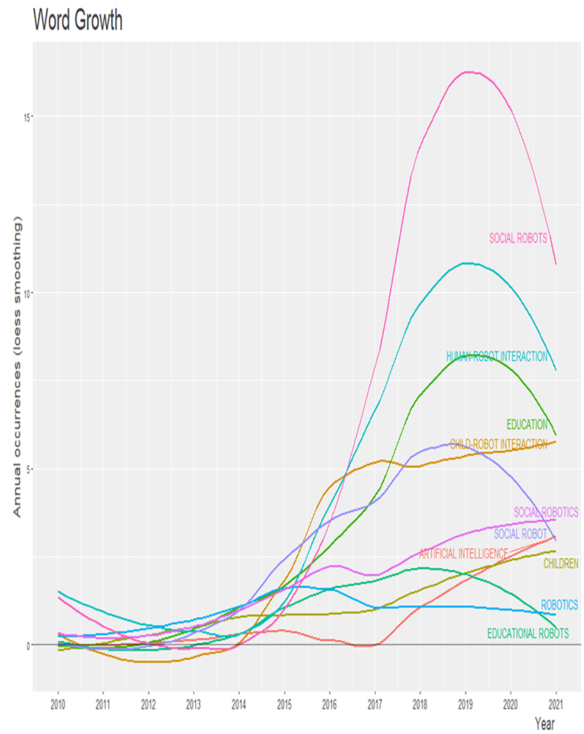

Figure 8. Word growth.

intelligent systems and computing' gradually increased from 2010 to 2017, rose rapidly from 2017 to 2020 and has been constant since. 'Lecture notes in computer science (including subseries lecture notes in artificial intelligence and lecture notes in bioinformatics)' rose gradually from 2010 to 2014, fell slightly by 2015, and rose again rapidly until 2019. It fluctuated again ever since. The 'International Conference Proceeding Series' has been almost constant, with a slight increase in 2017 and a slight fall in 2021.

4.7. Word growth and most relevant words

Shown above in Figure 8 is a curve highlighting the growth in use of some of the most used words in the topic of social robots in education. A growth curve is a graphical representation of how a particular quantity increases over time. Here, there is an increase in keywords from 2010 to 2021. The curve also shows that the usage of certain keywords has increased since 2015 and that there has been an even greater increase since 2017, even though there was a decrease between the two years with keywords such as educational robots and robotics. This research study calculated the most relevant words applied in the compilation of important documents that were analyzed. There were several words with occurrences, as shown in Figure 9, ranging from 0 to more than 75. The top 10 keywords listed above, marked with a blue diagram, show the comparison of the number of occurrences of each word usage and their relevance to the effectiveness of social robots in education. The word with the greatest number of occurrences and highest relevance to the topic is the word 'social robots', used more than 70 times with the most relevance, followed by 'human-robot interaction', 'used approximately 56 times and is shown with a dark blue bar. This highlights that education research based on social robots is closely associated with the keywords 'social robots' and 'human–robot interaction', which usually appear in research on this topic. The word 'education' is the third most common word, occurring approximately 41 times, followed by 'child robot interaction', which is used approximately 32 times.

4.8. Most locally cited countries

This research extracted the names of the countries in which the articles were most cited. Here, we present the 20 countries with the highest number of citations. The data are depicted in a bar diagram (Figure 10)

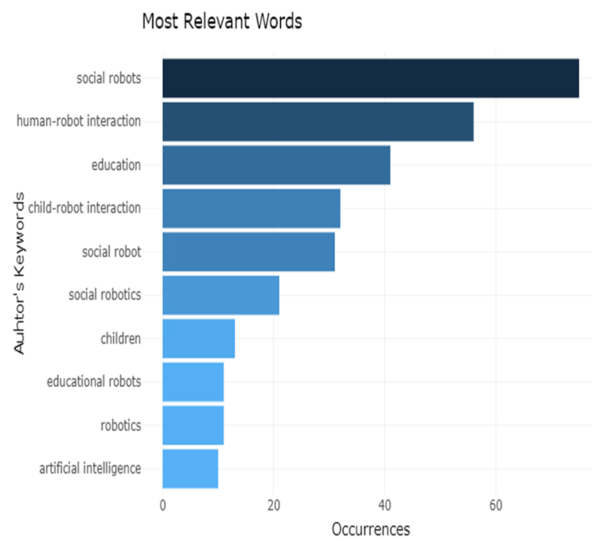

Figure 9. Most relevant words.

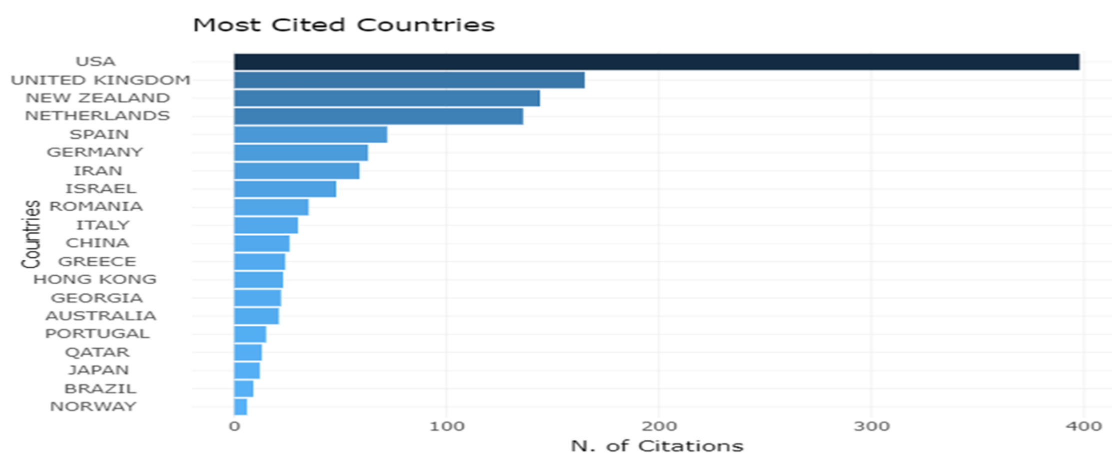

Figure 10. Most locally cited countries.

with blue bars, where the darkness of the bars indicates the degree of citations in each country. The country with the highest number of citations on this topic is the United States, with approximately 398 citations and 22,111 average article citations, followed by the United Kingdom, with 165 citations and a total of 15000 article citations on average. In third place is New Zealand, with 144 citations and 14000 article citations on average. This highlights that the research based on the topic of social robots in education is mostly cited in the U.S. with a difference of 233 from the following country, that is, the U.S.

4.9. Annual scientific production

This research study examined the pattern and duration of publication of articles on the topic of the effectiveness of social robots in education. As shown in Figure 11, the number of articles published on this topic increased over time. In the year 2010, there were 2 articles published. A stable increase can be observed over the years, increasing from 2 to 93 from 2010 to 2020.

5. Discussion

The overall results of the research analysis show that most research themes for social robots in education focus on the efficiency and effectiveness of incorporating robotic education in the global context through

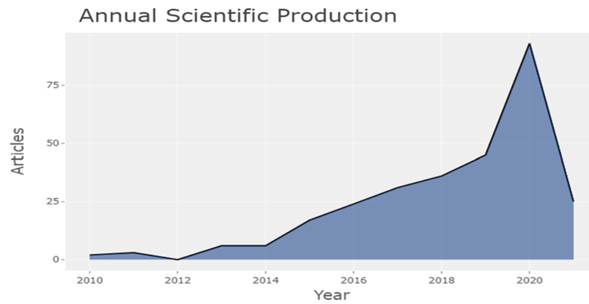

Figure 11. Annual scientific production.

different technological aspects. This is evident from similar results portraying that the words 'social robots' and 'education' are most widely used, which helps to clarify the importance of robotic education for pupils as well as for tutors. An elaborate bifurcation of authors and other findings was found, which helped us to determine which keywords were most commonly used.

This study shows that research on social robots in education in the global context has several valid explanations. First, the incorporation of social robots has helped researchers and academicians to showcase the potential of social robots wherein technology plays a pivotal role in creating learner and tutor companions in the form of educational robots. Second, as STEM education is a part and parcel of robotics, it helps researchers gauge the importance of revolving as an interdisciplinary or cross-disciplinary aspect. It is also evident that in robot education, researchers have paid increased attention to the subject integration of robot teaching and the design of curricula in science and engineering. Recently, STEM education has been found to be a key topic of education reform in different countries, and robot courses are considered an effective way to promote and develop STEM education (Riva & Riva, 2019).

The current bibliometric analysis provides a transparent picture of the status of various countries and their participation in terms of citations. A major part of most of the authors' works revolved around certain areas, such as child robot interaction and social robots. These findings show that the advent of social robots in education is young and flourishing and that academics should give more importance to carrying forward its application in education to strengthen and reinforce the education system. The findings also show the growth of journals in the domain.

In addition, the findings suggest that not all countries are pursuing robotic education due to a shortage of technology and funds. Countries in South Asia are gradually surmounting the education system by introducing artificial intelligence, but most of the countries are yet to take a move in the robotics world. The present bibliometric analysis gauged the pros and cons of robotic education whereby, when robots are employed as a learning agent and a tutor companion, the class is carried out in a positive way, contributing to the academic development of the students. The use of robotic platforms contributes to the learning process in children, which becomes attractive and interactive as the systems are designed to develop teamwork (Reich-Stiebert & Eyssel, 2015).

Most researchers have realized that robot education practices must focus on multidisciplinary integration and application practices and should not be limited to programming applications. It was found that robotic education can assist in learning a second language and help in creating positive impacts, especially in the development of treating autism. Current research discloses that the application of robots is an auxiliary tool that is conducive to and contributes to the development and growth of the pupil.

This bibliometric analysis also revealed that children could use robots, platforms, and sensors on KIBO as an introduction to robot teaching in preschool, which is beneficial for learning programming. This, in turn, has a positive impact on a child's computational thinking. The study highlights the fact that a child can learn to code from an early age. Educational robots foster the construction of a learner-centered, autonomous, flexible, and inquiry-based learning model when compared to traditional forms of education. A novel way of promoting the computational thinking ability of younger children is using educational robots.

We see a scattered vision of the research done on robot teaching and learning tools at present. The promotion and continuity of these tools should be explored further. With the smooth popularization of artificial intelligence, research on robot teaching tools should keep pace with the emerging trends of technological change so that robotic education can increase the vitality of sustainable development.

Furthermore, additional research is needed to substantiate the empirical evidence on the types of robots in education and the various predictors when tried attempting to research attitudes toward robots (Reich-Stiebert et al., 2019). Future researchers should use indicators or markers to determine the area of work and the years of publication to obtain information, as well as different journals that publish the highest quality research. By gathering the information contributed by these indicators, an influential robotic intervention can be successfully implemented (Lorenzo et al., 2021).

6. Future implications

The current study focused on improving learners' computational thinking with robots in education, which are designed to develop cognitive skills in children and adolescents. The results weigh the pros and cons that characterize concepts of learning from mistakes, teamwork, and adaptability to the future, encouraging enhanced self-esteem, proposing new initiatives and practical application—specifically, the STEM model truly depicted in the conceptual structure map. The study also highlights that the use of robots in higher education yields optimal results at all educational levels, which has also led to attempts to determine the cons and weaknesses associated with their implementation. This approach takes the spotlight away from traditional methods of teaching because of the difficulties in assembling the robot, and sometimes, the performance of robots may not meet expectations. The conceptual structure map and the thematic map originating from this bibliometric analysis weigh the importance of the actions implemented for scaffold learning.

The analysis derived from word maps and co-occurrence networks helps researchers visualize the generation of verbal and nonverbal outputs as a challenge, as does fruitful orchestrated timing because artificial or robotic social interaction is considered to be a formidable challenge in robotics and artificial intelligence.

Future recommendations suggested through this analysis imply that researchers look forward to finding remedies to address these challenges and overcoming the disadvantages of implementing social robots in education. Considering the abovementioned results and limitations of the conducted analysis, a few recommendations for researchers dealing with social robots in higher education may be formulated. By highlighting the existing presence and potential of social robots in the domain of education, this study intends to provide insight into the effectiveness and impact of socially interactive robots acting as learning agents whereas tutoring companions are supported by data extracted from research journals and articles. This study uses bibliometric analysis to prove the legitimacy of the topic with the help of the work of various authors. The analysis revealed that social robots, as virtual pedagogical agents, are built with the aim of assisting humans in tasks such as educational activities. They proved to be helpful when used with the best of intentions with which they are programmed.

7. Conclusion

Social robots in higher education are of substantial interest to several researchers from a wide variety of countries and from all continents where most of the studies being conducted in Greece shall not be omitted when analyzing different perspectives. Most of the subsisting research articles on social robots tend toward education and child robot interaction, which try to gauge the pros and cons of appearance for robot performance as a tutor, tool, or peer in the learning exercise. This study offers a foundation that strongly contributes to an anterior description bracing the fundamental logic of the Robotic Education antecedent by depicting the research articles published in different countries by various authors with the help of showcasing the keywords used interchangeably.

The benefits of robots in education are alarmingly high and increasingly popular, where millions of educational institutions no doubt opt for them as tools for classroom instruction in the near future. Because of their variety, the stages of educational robotics that are associated with their use, and the goals that can easily be accomplished with them, we can say that robots are here and now. Speech recognition is an insufficiently robust concept for allowing a robot to understand spoken utterances from learners. Studies highlight the shortcomings that can be resolved by adopting alternative input media with the help of touch screens that facilitate interaction. To build a fluent, contingent, and effective interaction between social robots and learners, there is a need for seamless integration of a flow of processes in robotics and artificial intelligence.

However, it is important to keep in mind the moral implications of such artificial participation in the process of learning and teaching. The conclusion of this study is that social robots prove to be useful for assisting in the process of earning; however, they cannot replace human tutors and learning companions. Even though social robots can assist students in learning in various ways, the original approach of educational technology is to support the learning process rather than replace human caregivers such as teachers or parents. This research inculcates the method of scientific analysis and measurement plugged around the theme of 'robot education'. The present study answers the research questions of what the main topics of research in social robots are and what are its research trends and knowledgebase by disclosing the frontiers of current robot education in the global context. The present research scanned the hotspots of robot education, which mainly included the influence of robot education on children as learner companions and teaching practices using robot education as a tutor companion from 2010 to 2020. With the rigor of in-depth research on robot education, the current study focused on changes in student thinking and the development of robot courses. However, as the topic grows, having a complete overview becomes challenging. For that purpose, we use bibliometrics, which is the application of computer-based techniques for the analysis of publication data; in this case, we use academic articles published in journals or conference proceedings. The significance of this is to encompass the application of robots to teach programming along with learning objects and teaching tools. These results provide a plethora of ideas and valuable indications to researchers and practitioners in the domain of robot education, which sets a platform for solving a series of barriers and problems encountered in the incorporation, development, and practice of robot education.

Disclosure statement

No potential conflict of interest was reported by the authors.

About the authors

Dr. Rashmi Yogesh Pai is an Associate Professor in the Department of Commerce, Manipal Academy of Higher Education Manipal, and has research expertise in employer branding and artificial intelligence, training & development, and organizational behaviour.

Dr Ankitha Shetty currently working as Assistant Professor and Research Co-ordinator at Department of Commerce, Manipal Academy of Higher Education, PhD Research Guide (Area of Marketing) Editorial Review Board Member of Asia Pacific Journal of Business Administration Emerald Publishers.

Ms. Tantri Keerthi Dinesh is a Research Scholar in the Department of Commerce, Manipal Academy of Higher Education, Manipal. Her research is in the field of Mindfulness and she has been conducting mindfulness interventions for human resource at workplace. She has expertise in systematic reviews and bibliometric tools.

Dr. Adithya D Shetty is an Associate Professor in the Department of Commerce, Manipal Academy of Higher Education, Manipal and a specialist in Logistics and supply chain area. His research interest also includes logistics operations pertaining to various sectors of economy.

ORCID

Adithya D. Shetty http://orcid.org/0000-0002-1314-7322

References

Backfisch, I., Lachner, A., Stürmer, K., & Scheiter, K. (2021). Variability of teachers' technology integration in the classroom: A matter of utility!. *Computers & Education*, *166*, 1. https://doi.org/10.1016/j.compedu.2021.104159

Baxter, P., Ashurst, E., Kennedy, J., Senft, E., Lemaignan, S., & Belpaeme, T. (2015). *The wider supportive role of social robots in the classroom for teachers* [Paper presentation]. 1st International Workshop on Educational Robotics at the Int. Conf. Social Robotics, pp. 1–17.

Belpaeme, T., Kennedy, J., Ramachandran, A., Scassellati, B., & Tanaka, F. (2018). Social robots for Education: A review. *Science Robotics*, *3*(21), eaat5954. https://doi.org/10.1126/scirobotics.aat5954

Beran, T. N., Ramirez-Serrano, A., Kuzyk, R., Fior, M., & Nugent, S. (2011). Understanding how children understand robots: Perceived animism in child–robot interaction. *International Journal of Human-Computer Studies*, *69*(7–8), 539–550. https://doi.org/10.1016/j.ijhcs.2011.04.003

Burda, Y. D., Volkova, I. O., & Gavrikova, E. V. (2020). Meaningful analysis of innovation, business and entrepreneurial ecosystem concepts. *Russian Management Journal*, *18*(1), 73–102. https://doi.org/10.21638/spbu18.2020.104

Collins, A., & Halverson, R. (2010). The second educational revolution: Rethinking education in the age of technology. *Journal of Computer Assisted Learning*, *26*(1), 18–27. https://doi.org/10.1111/j.1365-2729.2009.00339.x

Ekström, S., & Pareto, L. (2022). The dual role of humanoid robots in education: As didactic tools and social actors. *Education and Information Technologies*, *27*(9), 12609–12644. https://doi.org/10.1007/s10639-022-11132-2

Gittings, J. (2020). Alex J. Bellamy. World Peace (And How We Can Achieve It). Oxford: Oxford University Press, 2019. *Peace & Change*, *45*(4), 619–621. https://doi.org/10.1111/pech.12431

Kandlhofer, M., & Steinbauer, G. (2016). Evaluating the impact of educational robotics on pupils' technical- and social-skills and science related attitudes. *Robotics and Autonomous Systems*, *75*, 679–685. https://doi.org/10.1016/j.robot.2015.09.007

Kennedy, J., Baxter, P., Senft, E., & Belpaeme, T. (2016, April). *Heart vs hard drive: Children learn more from a human tutor than a social robot* [Paper presentation]. 2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI), pp. 451–452. https://doi.org/10.1109/HRI.2016.7451801

Lin, J., Li, Y., & Yang, G. (2021). FPGAN: Face deidentification method with generative adversarial networks for social robots. *Neural Networks: The Official Journal of the International Neural Network Society*, *133*, 132–147. https://doi.org/10.1016/j.neunet.2020.09.001

Lorenzo, G., Lledó, A., Pérez-Vázquez, E., & Lorenzo-Lledó, A. (2021). Action protocol for the use of robotics in students with autism spectrum disorders: A systematic-review. *Education and Information Technologies*, *26*(4), 4111–4126. https://doi.org/10.1007/s10639-021-10464-9

Lu, J., Ren, H., Guo, S., Gu, D., Wen, H., Qin, Y., Zhou, S., Hu, W., & Jiang, C. (2014). Ultra-wideband optical diode based on photonic crystal 90° bend and directional coupler. *Chinese Optics Letters*, *12*(10), 102301–102304. https://doi.org/10.3788/col201412.102301

Moral-Muñoz, J. A., Herrera-Viedma, E., Santisteban-Espejo, A., & Cobo, M. J. (2020). Software tools for conducting bibliometric analysis in science: An up-to-date review. *El Profesional de la Información*, *29*(1). https://doi.org/10.3145/epi.2020.ene.03

Mubin, O., Stevens, C. J., Shahid, S., Mahmud, A. A., & Dong, J.-J. (2013). A review of the applicability of robots in education. *Journal of Technology in Education and Learning*, *1*(209-0015), 13. https://doi.org/10.2316/Journal.209.2013.1.209-0015

Pachidis, T., Vrochidou, E., Kaburlasos, V. G., Kostova, S., Bonković, M., & Papić, V. (2019). Social robotics in education: State-of-the-art and directions. *Mechanisms and Machine Science*, *67*, 689–700. https://doi.org/10.1007/978-3-030-00232-9_72

Ramírez, J., Górriz, J. M., Ortiz, A., Cole, J. H., & Dyrba, M. (2020). Editorial: Deep learning in aging neuroscience. *Frontiers in Neuroinformatics*, *14*, 573974. Accessed 25 Apr. 2021. https://doi.org/10.3389/fninf.2020.573974

Reich-Stiebert, N., & Eyssel, F. (2015). Learning with educational companion robots? Toward attitudes on education robots, predictors of attitudes, and application potentials for education robots. *International Journal of Social Robotics*, *7*(5), 875–888. https://doi.org/10.1007/s12369-015-0308-9

Reich-Stiebert, N., Eyssel, F., & Hohnemann, C. (2019). Exploring university students' preferences for educational robot design by means of a user-centered design approach. *International Journal of Social Robotics*, *12*(1), 227–237. https://doi.org/10.1007/s12369-019-00554-7

Riva, G., & Riva, E. (2019). GOAL-ROBOTS: Goal-based open-ended autonomous learning robots. *Cyberpsychology, Behavior and Social Networking*, *22*(9), 615–616. https://doi.org/10.1089/cyber.2019.29162.ceu

Saerbeck, M., Schut, T., Bartneck, C., & Janse, M. D. (2010). Expressive robots in education: Varying the degree of social supportive behavior of a robotic tutor. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1613–1622). https://doi.org/10.1145/1753326.1753567

Sailer, M., Schultz-Pernice, F., & Fischer, F. (2021). Contextual facilitators for learning activities involving technology in higher education: The C♭-model. *Computers in Human Behavior*, *121*(4), 106794. https://doi.org/10.1016/j.chb.2021.106794

Share, P., & Pender, J. (2018). Preparing for a robot future? Social professions, social robotics and the challenges ahead. *Irish Journal of Applied Social Studies*, *18*(1), 4. https://doi.org/10.21427/D7472M

Smakman, M. H. J., Konijn, E. A., Vogt, P., & Pankowska, P. (2021). Attitudes toward social robots in education: Enthusiast, practical, troubled, sceptic, and mindfully positive. *Robotics*, *10*(1), 24. https://doi.org/10.3390/robotics10010024

Smakman, M., Vogt, P., & Konijn, E. A. (2021). Moral considerations on social robots in education: A multistakeholder perspective. *Computers & Education*, *174*, 104317. https://doi.org/10.1016/j.compedu.2021.104317

Tang, X., & Chu, J. (2022). Inclusive design: Task specified robots for elderly. *Advances in Education, Humanities and Social Science Research*, *1*(1), 82. https://doi.org/10.56028/aehssr.1.1.82

Teräs, M., Suoranta, J., Teräs, H., & Curcher, M. (2020). Post-Covid-19 education and education technology 'solutionism': A seller's market. *Postdigital Science and Education*, *2*(3), 863–878. https://doi.org/10.1007/s42438-020-00164-x

Tolksdorf, N. F., Viertel, F. E., & Rohlfing, K. J. (2021). Do shy preschoolers interact differently when learning language with a social robot? An analysis of interactional behavior and word learning. *Frontiers in Robotics and AI*, *8*, 676123. https://doi.org/10.3389/frobt.2021.676123

Van Eck, N. J., & Waltman, L. (2019). Accuracy of citation data in Web of Science and Scopus. Proceedings of the 16th International Conference of the International Society for Scientometrics and Informetrics, 17 June 2019, pp. 1087–1092, arxiv.org/abs/1906.07011, https://doi.org/10.48550/arXiv.1906.07011. Accessed 14 May 2021.

Wainer, J., Dautenhahn, K., Robins, B., & Amirabdollahian, F. (2014). A pilot study with a novel setup for collaborative play of the humanoid robot KASPAR with children with autism. *International Journal of Social Robotics*, *6*(1), 45–65. https://doi.org/10.1007/s12369-013-0195-x

Xie, H., Zhang, Y., Zeng, X., & He, Y. (2020). Sustainable land use and management research: A scientometric review. *Landscape Ecology*, *35*(11), 2381–2411. https://doi.org/10.1007/s10980-020-01002-y