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Research Article

Examination of Research Conducted on the Use of Artificial Intelligence in Science Education

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Abstract: The advancement of artificial intelligence (AI) has been significantly driven by developments in machine learning and neural networks. As AI becomes increasingly pervasive, its applications are diversifying, with notable penetration in sectors such as health, education, social media, robotics, and entertainment. One area in which AI is being deployed is science education. The objective of this study is to examine the research that incorporates AI within the field of science education. By analyzing trends in the reviewed studies, this research identifies the countries, institutions, journals and scholars that are the most prominent contributors to this field of enquiry. The findings suggest that the incorporation of artificial intelligence into science education is still in its infancy, with a paucity of widespread implementation. However, there is a discernible increase in the quantity of published works, with an emerging emphasis on the assessment of learning outcomes and the enhancement of academic performance. The findings indicate that the United States is the leading country in terms of publications related to AI in science education, accounting for 38% of the total contributions. Additionally, Türkiye has emerged as a notable contributor in this field, demonstrating a growing presence. The Journal of Science Education and Technology was identified as the preeminent journal publishing research on AI. Furthermore, the findings revealed that GPT was the most frequently utilized tool in this context. In light of these findings, it is recommended that future investigations into the application of artificial intelligence (AI) in science education employ a range of AI tools and explore the development of higher-order thinking skills.

Keywords: Artificial Intelligence, Bibliometric Analysis Science Education, Science Learning

1. Introduction

The development of artificial intelligence (AI), accompanied by the advent of technologies such as neural networks and machine learning (Wang, 2019), represents a significant advance in computing. In contrast, conventional AI is typically designed to address a specific set of challenges by reacting to distinct inputs and relying on existing datasets (Cheung et al., 2024; Page et al., 2018; Schlegel & Uenal, 2021), Conversely, generative artificial intelligence (GenAI) is engineered to produce novel content or data by recognizing patterns gleaned from training data (Dwivedi et al., 2023). While traditional AI is typically focused on analysis and forecasting, GenAI has the potential to generate novel content, thereby opening up new avenues for creativity and innovation (Abbott & Rothman, 2022). This shift indicates a transition towards an educational framework and societal landscape where AI technology increasingly aids individuals in addressing their challenges (Cooper et al., 2024). GenAI represents a valuable tool for fostering creativity, personalized learning, and inventive pedagogical approaches (Cheung et al., 2024; Perera & Lankathilake, 2023; García-Peñalvo et al., 2023). Through autonomous content creation, GenAI can furnish tailored learning resources, formulate practical exercises, and devise realistic scenarios or simulations for hands-on learning experiences (Mello et al., 2023). The advancement of this technology signals the advent of a new era of innovation, which will redefine the concept of intelligence by embracing the dynamic integration of human ingenuity and machine capabilities (Cooper & Tang, 2024).

In addition to the potential advantages offered by these technologies, there are also significant disadvantages and ethical concerns that must be considered (Mumtaz et al., 2024). Learning Analytics

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platforms have the capacity to provide detailed insights into student engagement, performance trends and learning processes. Nevertheless, the Council of Europe (2022) has identified a number of critical ethical issues pertaining to the potential impact of these technologies on the representation of students and teachers. In this context, existing research indicates that interactions with automated artificial systems may result in a reduction in the sense of control experienced by human operators (Berberian et al., 2012; Yusuf et al., 2024). Such a dependency may have a negative impact on human interaction, as it could lead to a decline in the quality of decision-making processes. Additionally, the gathering of personal and confidential data, such as mood analysis, gives rise to substantial ethical concerns, including the monitoring of activities pertaining to political views, ethnic identity, and sexual orientation (Tundrea, 2020). It is therefore of paramount importance to safeguard the privacy of individuals and guarantee the security of data during the utilization of such technologies. The effective utilization of educational technologies will be contingent upon a comprehensive consideration of their potential benefits, in addition to a rigorous addressing of the aforementioned ethical concerns. Furthermore, there is a substantial concern that the advent of new technologies may exacerbate existing inequalities in education, potentially exposing learners to biases and cultural barriers (Malik et al., 2024; Miao et al., 2021). This situation has the potential to negatively impact both the learning process and assessment strategies. For example, while pedagogical agents are designed to enhance educational experiences by emulating human interactions and cultivating positive emotions, they also give rise to concerns pertaining to emotional privacy and the character of virtual relationships (Hudlicka, 2016; Vučković & Sikimić, 2024). Consequently, ethical issues may emerge from competing interests that extend beyond individual users to their families. Discussions surrounding these matters frequently reflect the diverse viewpoints of various stakeholders, whose perspectives differ based on their associations with private companies, government bodies, research institutions, universities, or educational organizations (Popenici & Kerr, 2017). Kowalczuk-Waledziak et al. (2019) posit that the extant framework for teacher education is in need of reassessment, particularly at the nexus of ethical concerns and pedagogical practices. A participatory approach that actively involves educators could facilitate significant advancements in pedagogy (Chichekian & Benteux, 2022). Furthermore, a systematic review of the literature addressing the ethical dimensions of AI applications has revealed a notable lack of focus on ethical considerations, even in the context of the launch of various educational initiatives in schools (Mouta et al., 2023). Notwithstanding the existing challenges, a number of recent initiatives have been launched with the objective of addressing these pressing concerns and needs (Malik et al., 2024). Among these is the UNESCO AI Competence Framework for Educators, scheduled for introduction in 2024. The framework comprises a three-phase progression plan, which is designed to foster a human-centered approach, address ethical considerations related to AI, facilitate comprehension of the fundamental principles and applications of AI, integrate it into pedagogical practices, and utilize it for ongoing professional development (UNESCO, 2023). To illustrate, the AI4T initiative, which seeks to improve the training of educators and school administrators in the field of artificial intelligence, has been developed in a collaborative manner by France, Slovenia, Italy, Ireland, and Luxembourg. The ethical implications of AI in educational contexts have been identified as a key priority within the shared learning objectives established for professional development pathways across these nations. In this context, it is imperative that ethical challenges are effectively addressed in order to create a more inclusive and equitable educational landscape (Mouta et al., 2024).

A review of the last decade reveals that artificial intelligence (AI) has become increasingly pervasive and has exerted a significant influence across a range of domains, including health, education, social media, robotics, and entertainment (Su & Yang, 2022) AI technologies such as GPT-4 and Google Brain have been demonstrated to possess capabilities approaching those of humans, encompassing visual recognition, the ability to write programming code, and the capacity to solve mathematical problems (Cheung et al., 2024). Consequently, as AI has gained a significant presence in society, researchers have

emphasized the importance of improving students' AI literacy (Druga et al., 2019; Ng et al., 2022). Some scientists define AI literacy as comprising cognitive skills and emotional attitudes (Ng et al., 2021). These skills include the ability to comprehend, utilize, and assess AI, as well as to address ethical concerns. While these components align with cognitive skill levels in Bloom's taxonomy (Bloom et al., 1956), they also relate to values associated with AI technologies. However, these mental functions and emotional feelings regarding AI technologies conflict with epistemic considerations and call into question the accuracy of the information produced by the technology. Indeed, the majority of studies concentrate on knowledge and skills (Li & Ironsi, 2024). It would be beneficial to investigate which other variables are examined in the use of AI in the field of SE in order to provide guidance for future studies in this area and highlight potential gaps in the existing literature (Almasri, 2024). It is therefore important to determine the purposes of using AI in SE, the most examined variables, the authors and journals with high impact value, and other trends on this issue in the studies to be conducted. Furthermore, it is essential to investigate the potential effects of using AI in the field of SE in order to gain insight into the current status of AI in SE. Furthermore, the existing literature on the integration of AI in SE can provide insights into the effectiveness of this integration, which can in turn inform curriculum planning and teaching processes in science education (Riera-Negre et al., 2024). Consequently, this research can serve as a pioneering investigation into the present state of AI in SE, offering insights to inform the work of researchers, practitioners, and policymakers by identifying emerging trends. A bibliometric analysis on AI in SE is of particular importance given the rapid development of both fields. A comprehensive and systematic review of the extant literature is a crucial undertaking, as the growing deployment of AI in SE has the potential to usher in transformative shifts in the landscape of science pedagogy (Akhmadieva et al., 2023). The present study employs bibliometric methods to identify areas of prospective development and innovation, ascertain pivotal research trends, and furnish objective, data-driven insights into the current state of integration of AI in SE. In conclusion, given the rapidly increasing volume of publications in the field of SE, bibliometric analysis studies on AI in SE can be stated as an indispensable method to organize this accumulation, to obtain meaningful results, and to identify the most important studies that can guide educational practices and policy-making processes. Furthermore, as Heeg and Avraamidou (2023) have noted, such studies in the literature provide guidance for readers and researchers alike, illuminating potential avenues for future inquiry and underscoring the value of continued investigation in this domain. To illustrate the significance of this endeavor, it is essential to reference the review studies that delineate the evolving trends in research on AI in the field of SE.

When reviewing the existing literature on AI implementation in SE, Cheung et al. (2024) focused on investigating studies utilizing AI, particularly their treatment of epistemological insight. They noted a general need for more reference to this concept within the studies surveyed. Meanwhile, Jia et al. (2023) conducted a study delving into AI within SE, explicitly concentrating on experimental studies from 2013 to 2023. Their inquiry primarily centered on primary and secondary education levels, scrutinizing only those studies with full texts available. Their findings revealed a prevailing superficial integration of AI into SE, particularly noticeable at these educational tiers. The superficial integration of artificial intelligence (AI) has also permeated the domain of educational assessment, where its full potential remains largely untapped. A significant deficiency in the existing literature is the urgent necessity for the development of a comprehensive curriculum framework that effectively integrates AI into the processes of science education assessment. By contrast, Tahiru (2021) examined a wide range of academic subjects, encompassing disciplines such as language education (Liang et al., 2021) and catering to diverse target audiences, including students in higher education settings (Ouyang et al., 2022). It is particularly noteworthy that only one systematic review has explicitly focused on the application of AI within the context of STEM education (Xu & Ouyang, 2022). This paucity of comprehensive investigation suggests a substantial avenue for further inquiry in this pivotal domain. Xu and Ouyang (2022) have identified several noteworthy trends in relation to teaching methodologies,

contextual factors, and the level of educator involvement required to integrate AI within STEM education. The research conducted by Heeg and Avraamidou (2023) sought to answer three key questions: which AI application was utilized, which method was favored, and what was the impact of AI on the outcome. To this end, the researchers analyzed 22 studies. Akhmadieva et al. (2023) conducted a bibliometric analysis similar to the one presented here, but unlike our study, they limited their examination to the Scopus database. Moreover, their analysis of studies conducted between 2002 and 2023 diverged from our study in terms of both temporal scope and the specific studies included. The dissimilarity of the research questions posed by this study and our own study serves to differentiate the two studies from one another. This study will contribute to the existing body of knowledge in this field by employing bibliometric analysis. This analytical approach differs from previous studies in terms of the timeframe, sample selection criteria, methodological approach, and research objectives. The application of bibliometric analysis enables researchers to gain a comprehensive overview of their current scholarly position and to identify new avenues for future research. Furthermore, employing clustering techniques facilitates the identification of emerging publications, notable authors, and prominent journal groups, thereby offering valuable insights into the current landscape of AI research within SE. The research aimed to reveal trends in AI in SE by examining studies on AI in SE using bibliometric analysis. By examining the systematic literature review studies in the literature, it can be seen that the research in question differs from the above mentioned studies in terms of article inclusion criteria, time period of the studies examined, sample size, analysis technique, and specific research questions. Therefore, it can be said that the study will contribute to the literature in accordance with these characteristics. In conclusion, the present study is distinct from existing literature in this field, offering novel insights and contributions to the existing body of knowledge. This research aims to determine the research trends regarding the use of AI in SE by revealing the current situation in the literature and guiding researchers in their studies. The research questions of the study carried out for these purposes are as follows:

1. What is the yearly trend in AI publications within this area?
2. What is the ranking of the leading institutions and countries in research in this field?
3. What are the most frequently addressed topics concerning sustainable development goals?
4. What are the most preferred keywords in this field?
5. What are the terms used extensively in article summaries on AI?
6. Who are the leading authors in this field in the use of AI based on citation and co-citation analysis?
7. Which journals are the most frequently cited for articles on AI in SE, as determined by citation and co-citation analyses?

2. Method

The research was conducted to examine the trends of the studies conducted in Web of Science (WoS) for the use of AI in science education by systematic literature review. The research examined 80 articles on AI in SE in WoS with bibliometric analysis. The bibliometric technique involves applying quantitative techniques on research data such as citations publications and, authors (Broadus, 1987, Pritchard, 1969). Clustering techniques are effective in identifying trending relevant journals, publications and authors thus guiding researchers about the current status of the literature (Van Eck & Waltman, 2017). Bibliometric analysis is essential for determining trends in the literature on a particular research topic (Donthu et al., 2021; Falagas et al., 2006; Moral-Muñoz, et al., 2020; Özbey & Arıcı, 2024; Song et al., 2019). Bibliometric analysis is a technique that reveals the output of a specific research topic in a certain

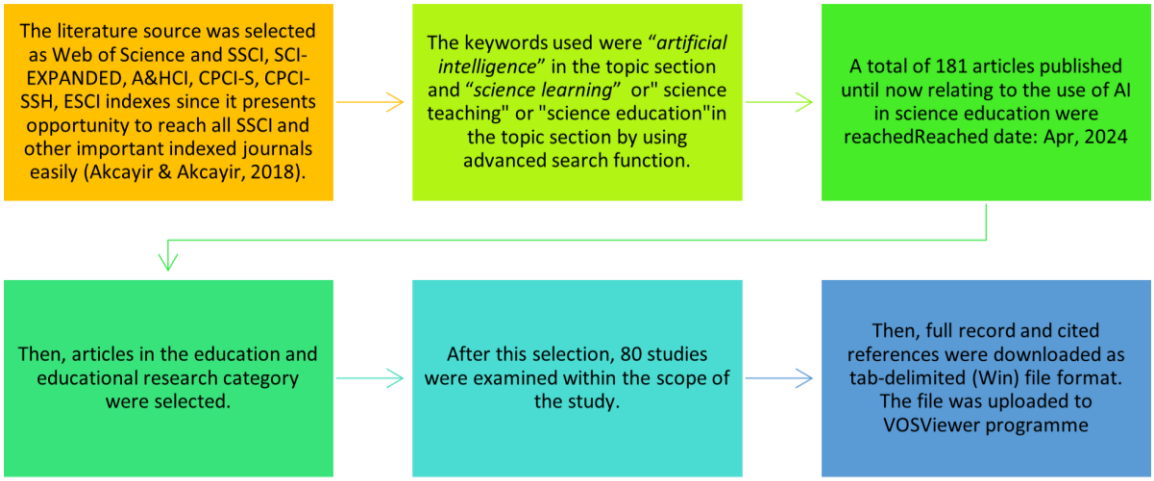
period with quantitative data (Chen et al., 2019). For this reason, this method was used to obtain numerical data on research trends in examining studies on AI in SE. The search included studies from the date of the first publication of the article on AI in SE to the date of this research (Last access date: 23 April 2024).

2.1. Article selection process

The articles to be examined in the study were analyzed using diagrams that explained the inclusion and exclusion of articles, as is common practice in review studies. The studies were identified using the PRISMA flow diagram (Moher et al., 2012), which is used as a publication for systematic reviews and meta-analyses. Additionally, the diagram utilized by Arici et al. (2019) was employed to identify the studies to be examined. Figure 1, which illustrates the review process and the stages of determining the included and excluded studies, is presented below.

Figure 1

Stages of Determining the Articles Included in the Research



2.2. Validity and reliability

2.2.1. The reliability of the data set

The data set utilized in the analysis was procured from a reliable and widely accepted academic database, such as WoS or Scopus. As such databases furnish data from reputable, peer-reviewed sources, the reliability of our dataset is considerable (Eker et al., 2019; Smith et al., 2015).

2.2.2. Validity of the data collection process

The keywords and search strategies were meticulously devised, and terms that are commonly utilized in literature reviews on the subject were selected. This process ensured the selection of articles that were pertinent to the research question of the study (Mukherjee et al., 2022).

2.2.3. Consistency of analysis methods

The methods most commonly employed in bibliometric analysis, including citation analysis and collaboration network analysis, were applied in accordance with established procedures. These methods represent established analytical techniques that have been validated in previous studies and are widely accepted in the literature (Van Eck & Waltman, 2010).

2.2.4. The reliability of the Results

To guarantee the reliability of the results, the findings were cross-checked with different analytical methods. For example, citation network analysis and word frequency analysis served to validate the findings in different dimensions (Zupic & Čater, 2015).

The aforementioned measures ensure that the study adheres to the requisite standards of validity and reliability. Furthermore, to enhance the representativeness of the data, a comprehensive time span was selected, spanning from the date of publication of the inaugural article to the date of the study's implementation (April 23, 2024). This comprehensive approach enhances the contribution of our study to the existing literature.

3. Findings

3.1. Publication countries/regions

Research data obtained from WoS and showing which countries the researchers examined belong to revealed that among these countries, the USA is the country with the most publications, 38%. Table 1 shows the publication regions of other studies examined within the scope of the study, which is presented below.

Table 1

Frequencies of Articles by Country

Ranking	***Countries***	***Frequencies of Articles***
1	USA	31
2	Spain	7
3	Germany	6
4	China	5
5	Türkiye	4
6	Australia	3
7	Brazil	3
8	Italy	3
9	Sweden	3
10	Canada	2

The results obtained in the analysis carried out to determine the widespread use of AI-related research in the field of SE among countries are presented in Figure 2.

Figure 2

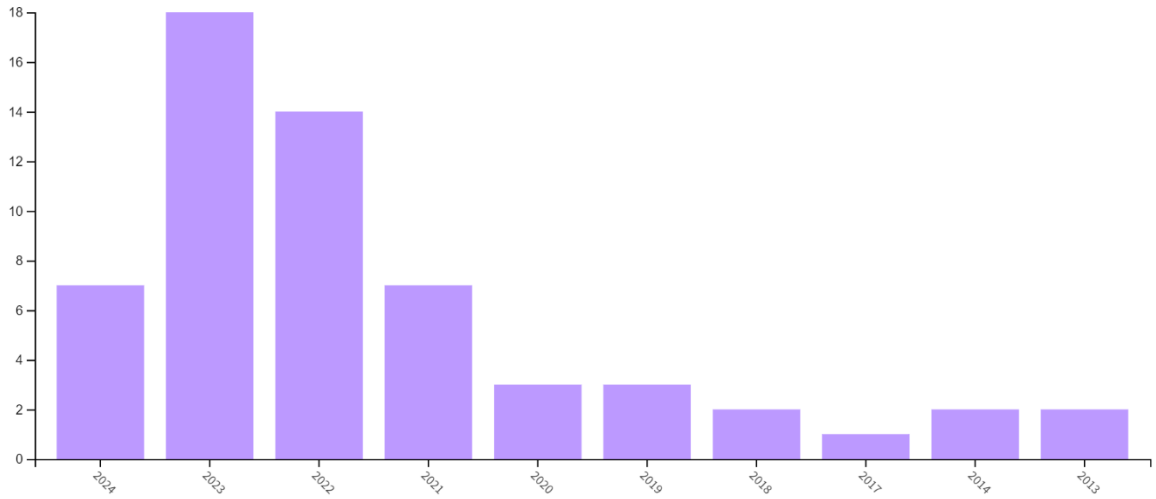
Examination of Articles on AI by Country in the Field of SE

3.2. Publication years

When WOS data is examined, it is seen that the first study on the use of AI in the field of AI was published in 1985. It has been understood that the number of publications is increasing, and the year in which the most publications were made is 2023. The chart showing the publication range of the studies is presented in Figure 3.

Figure 3

Density of Studies According to the Years They Were Published

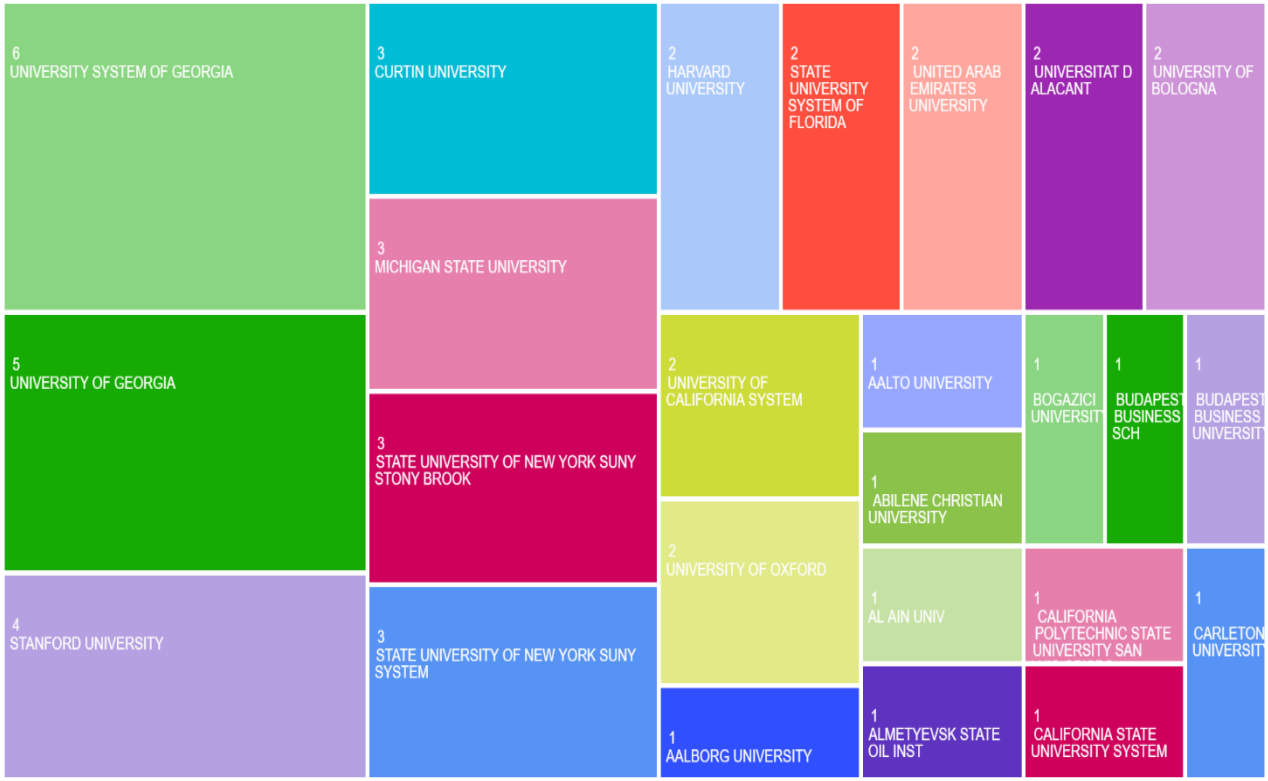


3.3. Institutions where research is conducted

The results obtained from the analyzes carried out to determine the prevalence of AI-related research conducted in the field of AI among institutions, institutes and universities are as shown in Figure 4.

Figure 4

Institutions that Publish the Most Articles on AI in the Field of SE



As illustrated in Figure 4, the University System of Georgia (F=6), the University of Georgia (F=5), Stanford University (F=4), and Curtin University (F=3) are the four institutions with the highest scores.

3.4. Sustainable development goals

Figure 5 illustrates the distribution of research on utilizing AI in SE across Sustainable development goals.

Figure 5

The Sustainable Development Goals are Discussed in Articles on AI in SE.

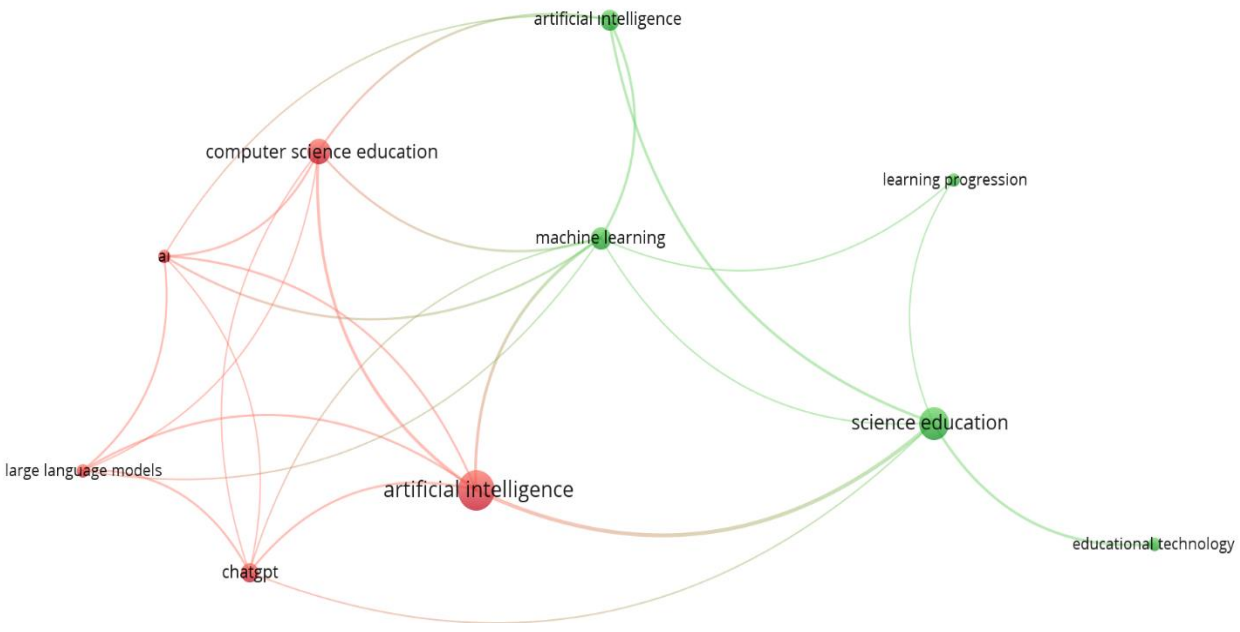
According to Figure 5, it is seen that Quality Education (F=47), Good Health and well-being (F=3), Responsible Consumption and Production (F=2), and No Poverty (f=1).

3.5. Frequently preferred keywords in articles on the use of AI technology in SE

The terms author keywords and co-occurrence were chosen to determine the most recurring keywords in studies on the use of AI in the field of SE. Number 3 was chosen as the frequency of repetition of the keyword, and it was seen that ten keywords matched it. Figure 5 below shows keywords and the relationships between them.

Figure 6

Common Keywords in AI-related Articles in SE



Based on Figure 6, the analysis delineated two distinct clusters, wherein the term "artificial intelligence" emerged as the most prevalent (f=27). Additionally, the examination underscores that keywords such as "SE" (f=18), "computer science education" (f=11), "machine learning" (f=9), "Chatgpt" (f=7), and "educational technology" (f=3) are among the most frequently employed terms in articles pertaining to AI within SE. These findings suggest a predominant focus on science education, computer science education, and machine learning within the articles. A selection of the most commonly occurring keywords identified in the analysis is shown in Table 2.

Table 2

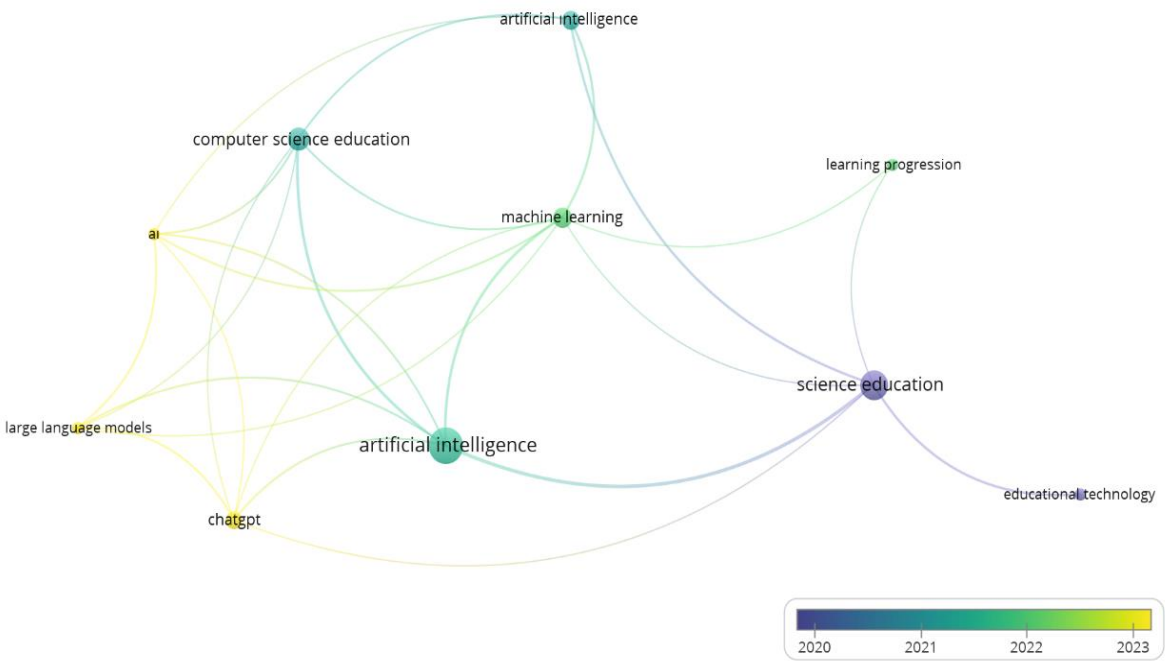
Frequencies of Commonly Occurring Keywords in AI Related Articles in SE

Ranking	Keyword	*f*	Overall Connection Capacity
1	Artificial Intelligence	27	20
2	Science Education	18	15
3	Computer Science Education	11	12
4	Machine Learning	9	15
5	ChatGPT	7	8
6	Educational Technology	3	3
7	Large Language Model	3	8
8	Learning Progression	3	2

In the analysis carried out to examine the change in the frequency of preference of keywords over time in studies using AI in the area of SE, it was seen that ChatGpt and the Large Language Model have been intensively studied recently. Figure 7 illustrates the progression in the number of articles published on these topics over time. This distribution provides insight into the growing scientific interest in these areas, particularly in the context of AI in SE.

Figure 7

Status of the Keywords Used in the Articles Over the Years

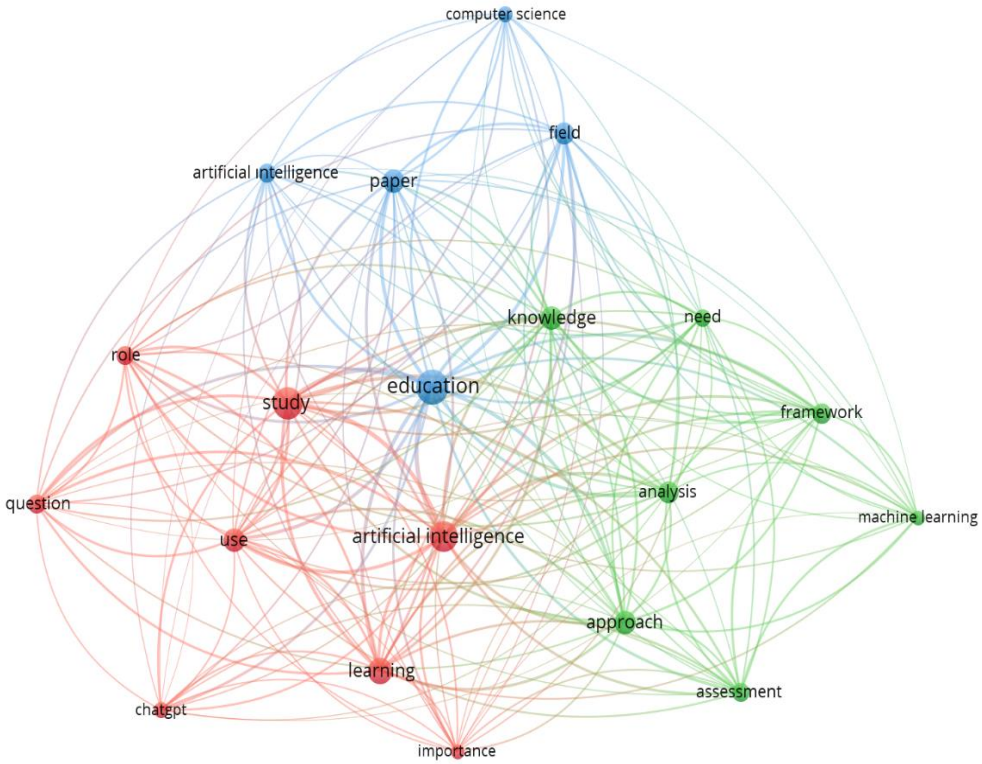


3.6. Repetitive words in research abstracts

In order to determine the frequently repeated words in the abstracts of the studies and thus the variables subject to the studies, the data set was run in the analysis programme. The programme investigated the abstracts of the studies by means of the binary counting method and generated the results. The minimum occurrence threshold for each term was set at 10 and 20 terms were automatically selected for inclusion. Figure 8 below shows the distribution of this data.

Figure 8

Trends in Frequently Used Words in Research Abstracts



Three clusters of twenty items are shown in Figure 8. In addition, Table 3 provides overviews of commonly repeated words in the abstracts of the articles.

Table 3

Frequencies of Certain Words in the Study Summaries

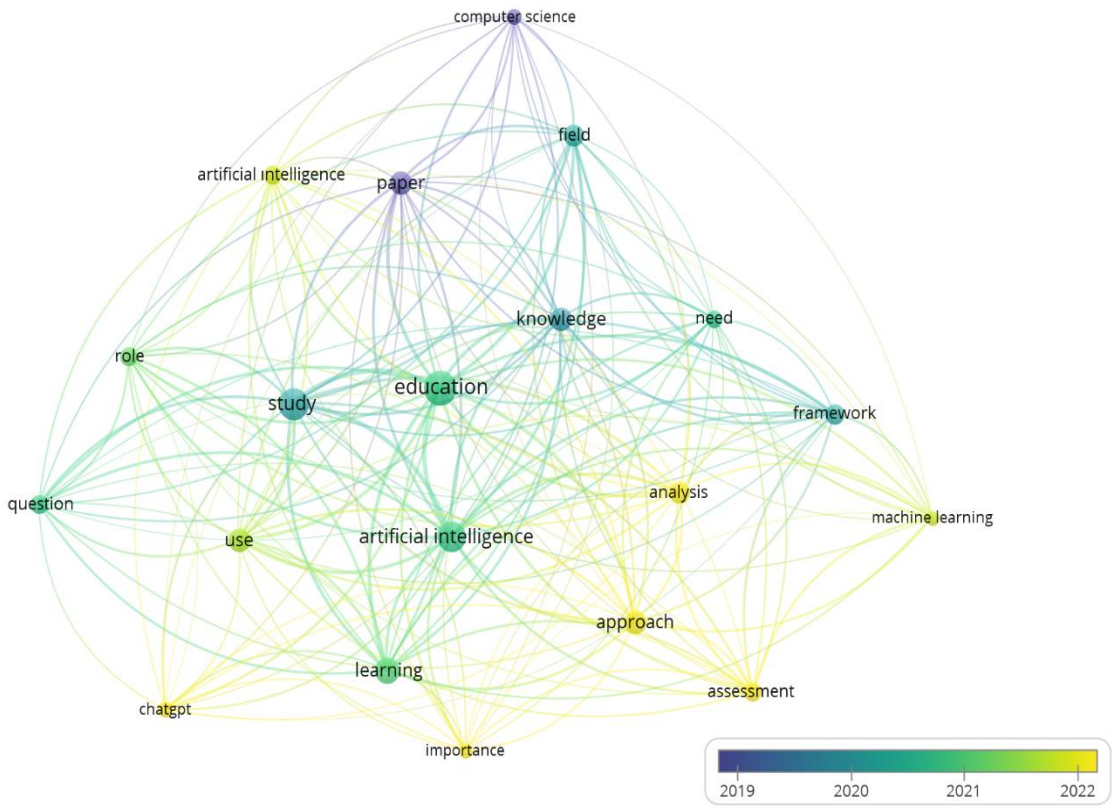
Ranking	Words in Abstract	f
1	Education	52
2	Study	41
3	Artificial Intelligence	40
4	Learning	29
5	Paper	24
6	Knowledge	23
7	Use	23
8	Approach	23
9	Analysis	21
10	Field	20

In Table 3, "education" is the most frequently utilized word in abstracts (f=52), suggesting that it is the dominant concept in articles related to AI in SE. Additionally, the data indicates that "study," "artificial intelligence," "learning," "paper," and "knowledge" are among the most prevalent keywords, with frequencies of f=41, f=40, f=29, f=24, and f=23, respectively (see Table 3).

The distribution of these words over the years shows that the articles focus mainly on evaluation, approach and, more recently, ChatGPT. Figure 9 shows the distribution by year of the most frequently used words in the abstracts of the articles.

Figure 9

Distribution of Most Used Words in Abstracts of Researches by Years



3.7. The most cited authors

Data were analyzed to identify the most cited authors in studies on the use of AI in the field of SE. In order to be included in the review, it is preferred that an author have at least two articles and at least two citations. 8 writers who met this condition were selected by the program. The resulting graph is shown in Figure 10 below.

Figure 10

Authors With the Largest Number of Citations

Figure 10 depicts two clusters and five links. Moreover, a summary of the authors included in the citation analysis is provided in Table 4 below.

Table 4

Summarised Results of the Most Frequently Cited Authors

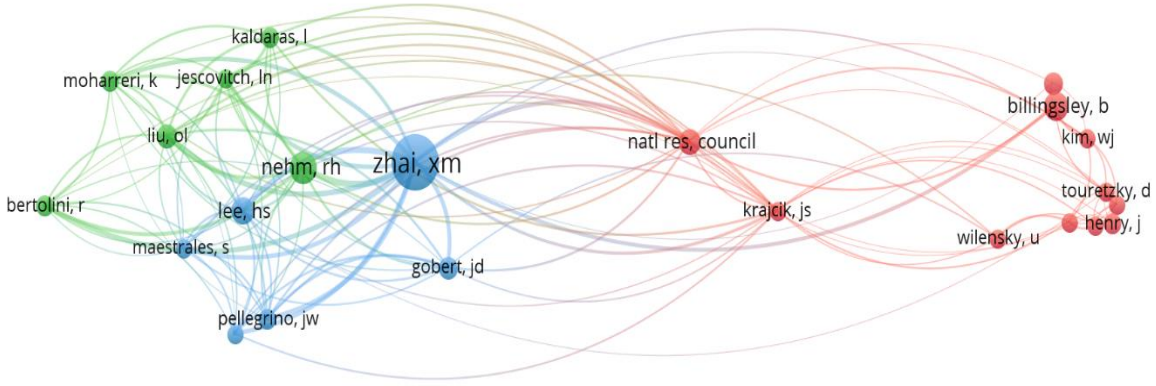
Ranking	***Authors***	**Documents**	**Citations**
1	Cooper, Grant	3	106
2	Chin, Doris B	2	72
3	Dohmen, Isla M	2	72
4	Schwartz, Daniel L	2	72
5	Zhai, Xiaoming	4	71
6	Nehm, Ross H	3	32
7	Haudek, Kevin C	2	5
8	Kaldaras, Leonora	2	5

Table 4 shows the number of citations for authors within the field, with Cooper Grant (106 citations), Chin Doris B (72citations), Dohmen, Isla M (72citations) and Schwartz, Daniel L (72citations) as the most cited authors.

A co-citation analysis was conducted utilizing the cited author method, with the minimum number of citations attributable to an author set at six. Twenty-three authors were identified as eligible for inclusion based on the specified criteria. This selection process is illustrated in Figure 11, which depicts the resulting graph of the analysis.

Figure 11

Common Citation Frequency of Top Authors



In Figure 11 there are five clusters and forty items with a total of 592 links. Table 6 below also provides summaries of the authors for the co-citation study.

Table 5

Summary of Top Citations (Co-Citation Analysis)

Ranking	*Authors*	Citations
1	Zhai X M	45
2	Nehm, R H	15
3	Blingsley, B	11
4	Lee, H S	12
5	National Research Council	10
6	Liu, OL	9
7	Gobert, JD	8
8	Cooper, G	8
9	Pellegrino, JW	7
10	Beltorini, R	7

As shown in Table 5, Zhai (45 citations), Nehm (15 citations), Billingsley (11 citations) and Lee (f=12) are the most frequently citing authors in the area.

3.8. Frequently cited journals

To create a visualization illustrating the highly referenced journals, a citation analysis was performed, emphasizing the origins of the publications. The minimum requirement for the count of documents associated with a source was set at 2, while the minimum threshold for citation count was established at 2. The system automatically determined the inclusion of 9 sources. The resultant visualization is depicted in Figure 12.

Figure 12

Citation Analysis of the Journals

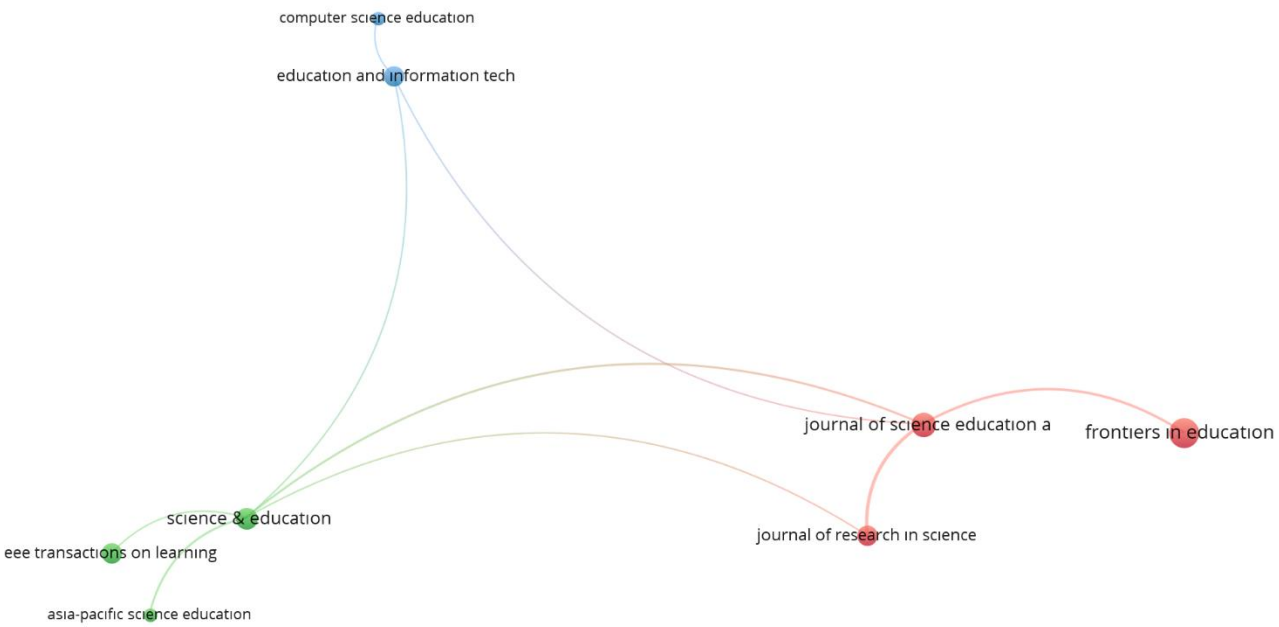


Figure 12 illustrates the presence of three clusters and nine entries across seventeen links. Moreover, Table 6 below presents a summary of the most frequently cited journals, as determined by a citation analysis.

Table 6

A Summarization of the Most Frequently Cited Journals

Ranking	*Journals*	Documents	Citations
1	Journal of Science Education and Technology	6	155
2	Educational Technology & Society	2	80
3	IEEE Transactions on Learning Technologies	6	54
4	Education and Information Technologies	4	51
5	Journal of Research in Science Teaching	4	33
6	Computer Science Education	2	20
7	Frontiers in Education	9	12
8	Science & Education	5	9
9	Asia-Pacific Science Education	2	5

Table 6 illustrates the journals with the greatest number of citations. These include the Journal of Science Education and Technology (155 citations, 6 documents), Educational Technology & Society (80 citations, 2 documents), IEEE Transactions on Learning Technologies (54 citations, 6 documents), and Education and Information Technologies (51 citations, 4 documents).

In order to conduct the aforementioned co-citation analysis, a visual representation of the sources most commonly referenced in conjunction with one another was produced using the cited sources method. This involved the identification of the sources that were most frequently cited in conjunction with

others. A minimum citation threshold of 15 was established, resulting in the automatic selection of 24 sources for inclusion. The resulting visualization is depicted in Figure 13.

Figure 13

Summary of Highly Referenced Journals

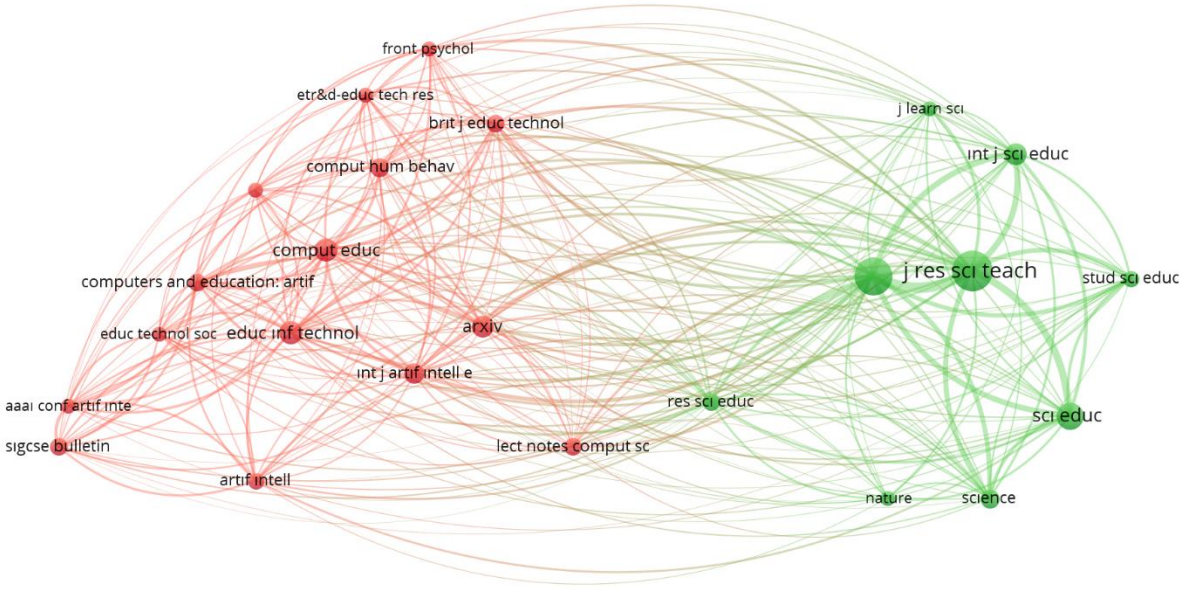


Figure 13 illustrates the presence of two clusters and a total of twenty-two items at six thousand one hundred fifty-two links. Furthermore, Table 8 presents a summary of the journals that have been cited most frequently (co-citation analysis).

Table 7

Summary of Highly Referenced Journals

Rating Rank	***Journals***	**Citations**
1	Journal of Research in Science Teaching	108
2	Journal of Science Education and Technology	97
3	Science & Education	50
4	Education and Information Technologies	36
5	Computers & Education	35
6	Arxiv	34
7	International Journal of Science Education	33
8	International Journal of Artificial Intelligence in Education	30
9	Science	25
10	Computers in Human Behavior	25

As demonstrated by Table 7, the four most frequently cited journals in the field are Journal of Research in Science Teaching (f=108), Journal of Science Education and Technology (f=97), Science & Education (f=50), and Education and Information Technologies (f=36).

4. Conclusion, Discussion and Recommendations

To ascertain the utilization of AI in SE, a bibliometric research methodology was employed. This entailed the implementation of a bibliometric mapping analysis, the findings of which revealed valuable insights. The research yielded several important insights regarding the use of AI in the field of social engineering. The results of the research indicate that approximately 38% of the relevant studies were conducted in the USA. The United States of America was followed by Spain, Germany, China, and Türkiye. The frequency of AI-related publications in these countries can be attributed to their endorsement of policies that facilitate the integration of technology in educational settings. The implementation of various policies to popularize the use of technology in these countries provides an explanation for this situation (Eşiyok & Demircioğlu, 2022). Similarly, Akhmadieva et al. (2023) analyzed studies in the Scopus database from 2002 to 2023 in the field of science education and revealed a ranking of the top three countries as the USA, the United Kingdom, and China. It was observed that Spain and the United Kingdom were assigned disparate rankings in the two studies. This discrepancy can be attributed to the utilization of disparate databases and varying timeframes. In the study conducted by Almasri (2024), the United States was ranked second, while Germany and Türkiye were ranked third and fourth, respectively. The following ranking is based on the time period between 2014 and 2023. The present study encompasses the entire time period under consideration. The results demonstrate that Türkiye and Germany have recently allocated greater resources to the development of AI, whereas the United States has maintained a consistent trajectory of advancement in this field. The results of the research indicate that the number of AI-related articles published annually has been increasing continuously since 1985, when the inaugural study was published. The year 2023 saw the greatest number of publications. The slope of the graph shows that this increase will continue. It can be predicted that the use of AI in SE will increase, especially with the emergence of new AI tools and their widespread use (Oh and Lee, 2024). Heeg and Avraamidou (2023) observed that the frequency of publications increased in conjunction with the advent of diverse AI applications that facilitated the advancement of research findings. Another result obtained from the research showed that the leading institutions that distribute research on the use of AI in SE on an institute and school basis are the University System of Georgia, University of Georgia, Stanford University, and Curtin University. It can be said that these universities are trending towards this field by foreseeing the future contributions of AI. As a matter of fact, since the limits of AI cannot be predicted, its contributions cannot be estimated in terms of reaching a conclusion about the extent to which it will be reached. It is an undeniable situation that especially higher education institutions tend to act quickly in terms of focusing on this technology in order to be among the leading institutions in this field (Cheung et al., 2024). In their 2023 study, Ng and colleagues elucidated this phenomenon by highlighting the more advantageous resources and infrastructure available at higher education institutions. The authors asserted that the absence of AI applications in alignment with those of other educational institutions, coupled with their limited access to AI or certain of its facilities, has positioned higher education institutions as the vanguard in this domain among all levels of education. It is therefore anticipated that in the future, more suitable and cost-effective types of AI technology will contribute to an increase in the use of this technology in SE at different levels of education (Heeg & Avraamidou, 2023; Ng et al., 2023).Another result obtained from the research stated that in the issues related to sustainable development goals, emphasis was placed on Quality Education, Good Health and Well Being, Responsible Consumption and Production, and No Poverty. This result has shown that AI has gained a visible level of importance compared to other fields, and that studies focusing on improving the quality of education are more intense. This situation is valuable in showing the need for quality education. The quality of education is one of the most important concepts that positively affects many variables (Al

Husaeni et al., 2024). Akhmadieva et al. (2023) asserted that this situation differs significantly between eastern and western countries. They further observed that the majority of western countries prioritize methodology in studies on AI, whereas eastern countries tend to prioritize educational applications. Moreover, Almasri (2024) asserted that studies tend to prioritize the examination of knowledge and skills. This situation demonstrates that articles on AI place particular emphasis on the cognitive abilities of students, with the objective of enhancing the quality of SE. A further outcome of the research indicated that the most commonly used keywords in articles about AI in SE were AI, science education, computer science education, machine learning, and educational technology. Especially the frequent use of machine learning and ChatGPT among these words can be explained by the fact that ChatGPT takes the lead in AI applications. The fact that the terms ChatGPT and large language models are used in the distribution of words according to years indicates that ChatGPT maintains its superiority even though there are many new tools in the use of AI in education (Cheung et al., 2024; Dunder et al., 2024). A review of the applications' functional areas reveals that, in particular, AI is employed for the purposes of evaluation and feedback. As the range of AI applications continues to expand, it is anticipated that the rate of growth in the utilization of AI in scientific education will also increase (Heeg & Avraamidou, 2023). In addition to the aforementioned applications, AI tools are currently employed in a multitude of domains, including the enhancement of productivity, the examination of data, and the customisation of user experiences. To illustrate, natural language processing (NLP) tools provide efficacious solutions for the analysis of human language, including text analysis and emotion detection (Russell & Norvig, 2016). In particular, highly sophisticated NLP models, such as GPT-3, offer significant convenience in the production of text. Machine learning (ML) is another AI tool that is employed in tasks such as prediction and classification through the process of learning on large datasets. In this field, popular platforms such as scikit-learn and TensorFlow are particularly noteworthy (Brownlee, 2016). The application of machine learning (ML) contributes to the process of decision-making by enhancing the accuracy of predictions in data-intensive sectors such as marketing and healthcare (Chollet, 2021).

Computer vision technologies also facilitate the analysis of visual data and are employed extensively in domains such as object recognition, face recognition and image classification (Kelleher & Tierney, 2018). In particular, within the domain of security, these technologies facilitate the automated analysis of images captured by security cameras. In contrast, voice recognition tools permit users to control devices via voice commands, with applications in numerous aspects of daily life, including the use of Siri or Google Assistant (Goodfellow et al, 2016). Finally, Robotic Process Automation (RPA) represents a significant time-saving measure, particularly within the business sector, through the automation of repetitive processes. These tools, which relieve the burden on the workforce, particularly in areas such as accounting and customer service, are rapidly becoming ubiquitous in business, with platforms such as UiPath and Automation Anywhere (Russell & Norvig, 2016). Upon examination of the most frequently occurring words in the abstracts of the articles, it becomes evident that the primary themes are education, study, AI, learning, paper, and knowledge. This situation has revealed that studies on AI in SE are mostly about knowledge and learning. It is understood that studies expressing high-level thinking skills have not been concentrated yet. In the distribution of these words according to years, the terms evaluation, approach and importance are used more in recent studies. This situation has especially shown that AI is used as an evaluation approach in studies conducted in SE (Haudek & Zhai, 2023). Furthermore, it is evident that the ethical principles pertaining to the utilization of AI are not addressed in the aforementioned studies. This can be attributed to the fact that these studies are still in their nascent stages (Domínguez Hernández & Owen, 2024). Finally, the most recent developments in AI demonstrate that its capabilities are not fully predictable, necessitating the use of limitations and ethical principles in its application. Regarding citations and co-citation analysis, the leading researchers in this field are Cooper, Chin, Dohmen, Zhai, Nehm, Blingsley. These results show that researchers are shifting their fields of study towards AI. In addition, it was determined that the most cited journals included

Journal of Science Education and Technology, Educational Technology & Society, IEEE Transactions on Learning Technologies, Science & Education and Education and Information Technologies. It is understood that these journals, which have an important place in SE, give priority to the subject of AI. These results obtained from the research have shown that it provides important and valuable information in terms of revealing research trends in the use of AI in SE, leading journals and researchers, and countries and institutions that prioritize AI.

It should be noted that the research is not without limitations. First and foremost, the search terms and strategies employed in the research can be regarded as a potential limitation in the process of identifying the included articles. Despite the use of rigorous and comprehensive search terms, it is possible that additional studies may have been included had alternative terms been employed. Moreover, the research was conducted using only the WoS database, which may have resulted in a more limited sample of literature. An examination of different databases might have yielded a different study sample. However, in the process of selecting the sample, particular attention was paid to the inclusion of important indexes and high-quality publications. Consequently, studies included in other indexes were excluded. The inclusion of studies in different indexes may result in a variety of changes to the results. Nevertheless, the validity, reliability, and academic reputation of the sources were rigorously evaluated at each stage of the process. In conclusion, the selected studies were identified through WoS searches at the time the research was conducted. Consequently, studies published subsequent to this date were not included in this research. Therefore, the results obtained are meaningful in line with this information. The findings of the research allow for the formulation of the following recommendations for researchers and future research:

- Given the dispersion of research efforts across various regions and the variances among countries, it's evident that the United States has spearheaded the bulk of AI-related research. Efforts can be channeled into emphasizing AI within educational programs in other nations.
- Collaborative international studies can be initiated by partnering with institutions boasting significant publication outputs or by reaching out to researchers affiliated with these institutions.
- Scholars' ought to scrutinize the contributions of prominent researchers and contemplate submitting their work to reputable journals or seeking publication opportunities therein.
- Studies on the use of AI in SE focus more on information and evaluation, and studies on different skills and subjects can be emphasized.
- It is imperative that educators and those aspiring to become educators are made aware of the latest developments in the field of AI. Furthermore, they should be provided with training on the use of different AI tools, and the ethical principles that should be adhered to when using them.
- A more comprehensive understanding can be achieved by examining studies across a range of indexes.
- The study revealed a notable increase in the frequency of publications originating from Türkiye in recent times. A review of Türkiye-based studies allows for the examination of trends and comparison with international literature.

References

Abbott, R., & Rothman, E. (2022). *Disrupting creativity: Copyright law in the age of generative artificial intelligence*. Florida Law Review, *75*, 1141. Retrieved from https://heinonline.org/HOL/LandingPage?handle=hein.journals/uflr75&div=34&id=&page=

AI4T. (2024). *Artificial intelligence for and by teachers*. Retrieved from https://www.ai4t.eu/

Akhmadieva, R. S., Udina, N. N., Kosheleva, Y. P., Zhdanov, S. P., Timofeeva, M. O., & Budkevich, R. L. (2023). Artificial Intelligence in Science Education: A Bibliometric Review. *Contemporary Educational Technology*, *15*(4), ep460. https://doi.org/10.30935/cedtech/13587

Al Husaeni, D. F., Al Husaeni, D. N., Nandiyanto, A. B. D., Rokhman, M., Chalim, S., Chano, J., ... & Roestamy, M. (2024). How technology can change educational research? definition, factors for improving quality of education and computational bibliometric analysis. *ASEAN Journal of Science and Engineering*, *4*(2), 127-166. https://doi.org/10.17509/ajse.v4i2.62045

Almasri, F. (2024). Exploring the impact of artificial intelligence in teaching and learning of science: A systematic review of empirical research. *Research in Science Education*, *54,* 1-21. https://doi.org/10.1007/s11165-024-10176-3

Arici, F., Yildirim, P., Caliklar, Ş., & Yilmaz, R. M. (2019). Research trends in the use of augmented reality in science education: Content and bibliometric mapping analysis. *Computers & Education*, *142*, 103647. https://doi.org/10.1016/j.compedu.2019.103647

Berberian, B., Sarrazin, J. C., Le Blaye, P., & Haggard, P. (2012). Automation technology and sense of control: A window on human agency. *PLoS ONE, 7*, e34075. https://doi.org/10.1371/journal.pone.0034075

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). Taxonomy of educational objectives: The classification of educational goals. *Handbook 1: Cognitive domain* (pp. 201–207). New York: McKay.

Broadus, R. N. (1987). Toward a definition of "bibliometrics". *Scientometrics*, *12*, 373-379. https://doi.org/10.1007/BF02016680

Brownlee, J. (2016). *Machine learning mastery with Python: understand your data, create accurate models, and work projects end-to-end*. Machine Learning Mastery.

Büyüköztürk, Ş., Kılıç Çakmak, E., Akgün, Ö., Karadeniz, Ş., & Demirel, F. (2021). *Scientific research methods in education.* Pegem.

Cooper, G., Tang, K. S., & Rappa, N. (2024). Generative artificial intelligence as epistemic authority? Perspectives from higher education. In H. Crompton & D. Burke (Eds.), *Artificial intelligence applications in higher education: Theories, ethics, and case studies for schools*. Routledge (in press).

Chen, X., G. Yu, G, Cheng., & T, Hao. (2019). Research topics, author profiles, and collaboration networks in the top-ranked journal on educational technology over the past 40 years: A bibliometric analysis. *Journal of Computers in Education, 6*(4), 563–585. https://doi.org/10.1007/s40692-019-00149-1

Cheung, K. K. C., Long, Y., Liu, Q., & Chan, H. Y. (2024). Unpacking Epistemic Insights of Artificial Intelligence (AI) in Science Education: A Systematic Review. *Science & Education*, 1-31. https://doi.org/10.1007/s11191-024-00511-5

Chollet, F. (2021). *Deep learning with Python*. Simon and Schuster.

Cope, B., Kalantzis, M., & Searsmith, D. (2021). Artificial intelligence for education: Knowledge and its assessment in AI-enabled learning ecologies. *Educational Philosophy and Theory, 53*(12), 1229–1245. https://doi.org/10.1080/001318572020.1728732

Council of Europe. (2022). *Artificial intelligence and education: A critical view through the lens of human rights, democracy and the rule of law*. Retrieved from https://rm.coe.int/prems-092922-gbr-2517-ai-and-education-txt-16x24-web/1680a956e3

Chichekian, T., & Benteux, B. (2022). The potential of learning with (and not from) artificial intelligence in education. *Frontiers in Artificial Intelligence, 5*, 903051. https://doi.org/10.3389/frai.2022.903051

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of business research*, *133*, 285-296. https://doi.org/10.1016/j.jbusres.2021.04.070

Domínguez Hernández, A., & Owen, R. (2024). 'We have opened a can of worms': Using collaborative ethnography to advance responsible artificial intelligence innovation. *Journal of Responsible Innovation*, *11*(1), 2331655. https://doi.org/10.1080/23299460.2024.2331655

Druga, S., Vu, S. T., Likhith, E., & Qiu, T. (2019). Inclusive AI literacy for kids around the world. In *Proceedings of FabLearn 2019* (pp. 104-111).

Dunder, N., Lundborg, S., Wong, J., & Viberg, O. (2024, March). Kattis vs ChatGPT: Assessment and evaluation of programming tasks in the age of artificial intelligence. In *Proceedings of the 14th Learning Analytics and Knowledge Conference* (pp. 821-827).

Dwivedi, Y. K., Kshetri, N., Hughes, L., Slade, E. L., Jeyaraj, A., Kar, A. K., Baabdullah, A. M., Koohang, A., Raghavan, V., Ahuja, M., Albanna, H., Albashrawi, M. A., Al-Busaidi, A. S., Balakrishnan, J., Barlette, Y., Basu, S., Bose, I., Brooks, L., Buhalis, D., … & Wright, R. (2023). Opinion paper: "So what if ChatGPT wrote it?" multidisciplinary perspectives on opportunities, challenges and implications of generative conversational AI for research, practice and policy. *International Journal of Information Management*, *71*, 102642. https://doi.org/10.1016/j.ijinfomgt.2023.102642

Eker, S., Rovenskaya, E., Langan, S., & Obersteiner, M. (2019). Model validation: A bibliometric analysis of the literature. *Environmental Modelling & Software*, *117*, 43-54. https://doi.org/10.1016/j.envsoft.2019.03.009

Eşiyok, S., & Demircioğlu, M. (2022). OECD ülkelerinin endüstri 4.0 düzeylerinin CRITIC ve CODAS yöntemleri ile değerlendirilmesi [Evaluation of industry 4.0 levels of OECD countries using CRITIC and CODAS methods]. *İstanbul Ticaret Üniversitesi Sosyal Bilimler Dergisi*, *21*(43), 377-398. https://doi.org/10.46928/iticusbe.1076484

García-Peñalvo, F. J., Llorens Largo, F., & Vidal, J. (2023). *The new reality of education in the face of advances in generative artificial intelligence.* https://doi.org/10.5944/ried.27.1.37716

Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep learning*. MIT Press.

Haudek, K. C., & Zhai, X. (2023). Examining the Effect of Assessment Construct Characteristics on Machine Learning Scoring of Scientific Argumentation. *International Journal of Artificial Intelligence in Education*, 1-28. https://doi.org/10.1007/s40593-023-00385-8

Heeg, D. M., & Avraamidou, L. (2023). The use of Artificial intelligence in school science: a systematic literature review. *Educational Media International*, *60*(2), 125-150. https://doi.org/10.1080/09523987.2023.2264990

Hudlicka, E. (2016). Virtual affective agents and therapeutic games. In D. D. Luxton (Ed.), *Artificial Intelligence in Behavioral and Mental Health Care* (pp. 81–115). Elsevier.

Jia, F., Sun, D., & Looi, C. K. (2024). Artificial intelligence in science education (2013–2023): Research trends in ten years. *Journal of Science Education and Technology*, *33*(1), 94-117. https://doi.org/10.1007/s10956-023-10077-6

Karagöz, B., & Şeref, İ. (2020) A review of articles on the writing skill: Trends in the web of science database abstract. *Journal of Mother Tongue Education, 8*(1), 67-86. https://doi.org/10.16916/aded.619090

Kelleher, J. D., & Tierney, B. (2018). *Data science*. MIT press.

Kowalczuk-Waledziak, M., Korzeniecka-Bondar, A., Danilewicz, W., & Lauwers, G. (Eds) (2019). *Rethinking teacher education for the 21st century. Trends, challenges and new directions*. Verlag Barbara Budrich. Retrieved from https://library.oapen.org/bitstream/handle/20.500.12657/23733/1006411.pdf?sequence=1&isAllowed=y

Li, Z., & Ironsi, C. S. (2024). The Efficacy of Generative Artificial Intelligence in Developing Science Education Preservice Teachers' Writing Skills: An Experimental Approach. *Journal of Science Education and Technology*, 1-12. https://doi.org/10.1007/s10956-024-10148-2

Malik, A., Khan, M. L., Hussain, K., Qadir, J., & Tarhini, A. (2024). AI in higher education: Unveiling academicians' perspectives on teaching, research, and ethics in the age of ChatGPT. *Interactive Learning Environments*, 1-17. https://doi.org/10.1080/10494820.2024.2409407

Mello, R. F., Freitas, E., Pereira, F. D., Cabral, L., Tedesco, P., & Ramalho, G. (2023). *Education in the age of generative AI: Context and recent developments.* arXiv preprint. https://doi.org/10.48550/arXiv.2309.12332

Miao, F., Holmes, W., Huang, R., & Zhang, H. (2021). *AI and education – Guidance for policy-makers.* United Nations Educational, Scientific and Cultural Organization. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000376709

Moher, D., Stewart, L., & Shekelle, P. (2012). Establishing a new journal for systematic review products. *Systematic reviews*, *1*, 1-3. https://doi.org/10.1186/2046-4053-1-1

Mouta, A., Pinto-Llorente, A. M., & Torrecilla-Sánchez, E. M. (2023a). Uncovering blind spots in education ethics: Insights from a systematic literature review on artificial intelligence in education. *International Journal of Artificial Intelligence in Education, 34*, 1166-1205. https://doi.org/10.1007/s40593-023-00384-9

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. *Profesional de la información/Information Professional*, *29*(1), 1-20. https://doi.org/10.3145/epi.2020.ene.03

Mouta, A., Torrecilla-Sánchez, E. M., & Pinto-Llorente, A. M. (2024). Comprehensive professional learning for teacher agency in addressing ethical challenges of AIED: Insights from educational design research. *Education and Information Technologies*, 1-45. https://doi.org/10.1007/s10639-024-12946-y

Mukherjee, D., Lim, W. M., Kumar, S., & Donthu, N. (2022). Guidelines for advancing theory and practice through bibliometric research. *Journal of business research*, *148*, 101-115. https://doi.org/10.1016/j.jbusres.2022.04.042

Mumtaz, S., Carmichael, J., Weiss, M., & Nimon-Peters, A. (2024). Ethical use of artificial intelligence based tools in higher education: Are future business leaders ready?. *Education and Information Technologies*, 1-27. https://doi.org/10.1007/s10639-024-13099-8

Ng, D. T. K., Leung, J. K. L., Chu, S. K. W., & Qiao, M. S. (2021). Conceptualizing AI literacy: An exploratory review. *Computers and Education: Artificial Intelligence, 2*, 1-11. https://doi.org/10.1016/j.caeai.2021.100041

Ng, D. T. K., Lee, M., Tan, R. J. Y., Hu, X., Downie, J. S., & Chu, S. K. W. (2023). A review of AI teaching and learning from 2000 to 2020. *Education and Information Technologies*, *28*(7), 8445-8501. https://doi.org/10.1007/s10639-022-11491-w

Oh, P. S., & Lee, G. G. (2024). Confronting Imminent Challenges in Humane Epistemic Agency in Science Education: An Interview with ChatGPT. *Science & Education*, 1-27. https://doi.org/10.1007/s11191-024-00515-1

Özbey, D., & Arıcı, F. (2024). Examining the researches on the use of augmented reality technology at primary school level. *Anatolian Journal of Language and Education, 2*(1), 29-46. Retrieved from https://dergipark.org.tr/en/pub/anadoluded/issue/85678/1501045

Page, J., Bain, M., & Mukhlish, F. (2018). *The risks of low level narrow artificial intelligence. In 2018 IEEE international conference on intelligence and safety for robotics* (ISR) (pp. 1-6). IEEE.

Perera, P., & Lankathilaka, M. (2023). Preparing to Revolutionize Education with the Multi-Model GenAI 246. Tool Google Gemini? A Journey towards Effective Policy Making. *Journal of Advances in Education and Philosophy*, *7*(8). 246-253. https://doi.org/10.36348/jaep.2023.v07i08.001

Popenici, S. A., & Kerr, S. (2017). Exploring the impact of artificial intelligence on teaching and learning in higher education. *Research and Practice in Technology Enhanced Learning, 12*(1), 22. https://doi.org/10.1186/s41039-017-0062-8

Pritchard, A. (1969). Statistical bibliography or bibliometrics. *Journal of documentation*, *25*, 348. Retrieved from https://cir.nii.ac.jp/crid/1570009750342049664

Riera-Negre, L., Hidalgo-Andrade, P., Rosselló, M. R., & Verger, S. (2024, February). Exploring support strategies and training needs for teachers in navigating illness, bereavement, and death-related challenges in the classroom: a scoping review supporting teachers in classroom grief and loss. In *Frontiers in Education* (Vol. 9, p. 1328247). Frontiers Media SA.

Russell, S. J., & Norvig, P. (2016). *Artificial intelligence: a modern approach*. Pearson.

Schlegel, D., & Uenal, Y. (2021). A perceived risk perspective on narrow artificial intelligence. In *PACIS* (p. 44).

Shubhendu, S., & Vijay, J. F. (2013). Applicability of artificial intelligence in different fields of life. Retrieved from https://www.semanticscholar.org/paper/Applicability-of-Artificial-Intelligence-in-Fields-Shubhendu-Vijay/2480a71ef5e5a2b1f4a9217a0432c0c974c6c28c

Smith, L. A., & Petersen, A. C. (2015). Variations on reliability: connecting climate predictions to climate policy. In *Error and uncertainty in scientific practice* (pp. 137-156). Routledge.

Su, J., Zhong, Y., & Ng, D. T. K. (2022). A meta-review of literature on educational approaches for teaching AI at the K-12 levels in the Asia-Pacific region. *Computers and Education: Artificial Intelligence, 3,* 1-18. https://doi.org/10.1016/j.caeai.2022.100065

Tundrea, E. (2020). Artificial Intelligence in Higher Education: Challenges and opportunities. *INTED2020 Proceedings,* 2041–2049. https://doi.org/10.21125/inted.2020.0644

UNESCO. (2023a). *Guidance for Generative AI in Education and Research*. United Nations Educational, Scientific and Cultural Organization. Retrieved from https://www.unesco.org/en/open-access/cc-sa.

UNESCO. (2023b). *Draft AI competency frameworks for teachers and for school students*. Retrieved from https://www.unesco.org/en/digital-education/ai-future-learning/competency-frameworks

Van Eck, N. J., & Waltman, L. (2017). Citation-based clustering of publications using CitNetExplorer and VOSviewer. *Scientometrics*, *111*(2), 1053-1070. https://doi.org/10.1007/s11192-017-2300-7

Van Eck, N., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. S*cientometrics*, *84*(2), 523-538. https://doi.org/10.1007/s11192-009-0146-3

Vučković, A., & Sikimić, V. (2024). Global justice and the use of AI in education: ethical and epistemic aspects. *AI & SOCIETY*, 1-18. https://doi.org/10.1007/s00146-024-02076-x

Wang, P. (2019). On defining artificial intelligence. *Journal of Artificial General Intelligence*, *10*(2), 1-37. https://doi.org/10.2478/jagi-2019-0002

Yusuf, A., Pervin, N., & Román-González, M. (2024). Generative AI and the future of higher education: A threat to academic integrity or reformation? Evidence from multicultural perspectives. *International Journal of Educational Technology in Higher Education*, *21*(1), 1-29. https://doi.org/10.1186/s41239-024-00453-6

Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. *Organizational research methods*, *18*(3), 429-472. https://doi.org/10.1177/1094428114562629

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