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Research trends in engineering education research through bibliometric analysis

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Abstract

This study aimed to explore research trends in engineering education research through bibliometric analysis. This review comprised studies indexed in the Scopus database between 2014 and 2023. In total, 6,338 articles were examined using the bibliometric analysis method. The results revealed an increase in the number of publications in the research on engineering education from 2014 to 2023. The results also showed that most of the top-10 authors are from the USA and slight collaborations between research groups. The results also revealed that most institutions with the highest publications and citations are from the USA, a leading country in engineering education research, and only three are from other countries, Denmark, Spain, and Sweden. Also, we found that the top-three journals are the periodicals that publish articles specifically on engineering education. The results regarding research trends revealed the existence of research on participants' self-efficacy beliefs, experiences, and perceptions and the effects of education technology practices on learning outcomes and teaching methods like project-based learning and problem-solving. Additionally, the research trends were found on design skills, decision-making, product design practices and professional development, technology integration practices, and teaching practices using artificial intelligence. Based on the results, we made implications for further studies.

Keywords: engineering education, bibliometric analysis, research trends, STEM education

INTRODUCTION

Engineering education has attracted considerable research attention because of its potential to answer overarching and big questions (Streveler & Smith, 2006). There has been a marked shift in this field toward more outstanding promotion of the common good and social justice among students (Cech, 2013). Integrating engineering design into technology education has further emphasized the importance of engineering education (Fan & Yu, 2015). Reform documents in this field highlighted advances in understanding students' engineering and science learning. It emphasized the commonalities with other science-based education research programs (Singer & Smith, 2013). In addition, Engineering education aims to provide learners with an understanding of the problems and try to solve them by finding new ways (Adams et al., 2011). Hence, encouraging students to study and have a career in engineering fields has become an aim of engineering education programs (Wendell et al., 2019). Moreover, engineering education research has an interdisciplinary nature (Bodnar et al., 2022). The importance of engineering education has attracted attention from scholars and educators due to its multifaceted nature, potential to address societal challenges, and impact on

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Contribution to the literature

- There is a lack of analysis of research trends in engineering education research through a bibliometric analysis covering a huge number of publications.
- This study fills a gap by conducting a bibliometric analysis to provide a thorough summary of research in engineering education from 2014 to 2023.
- The number of publications and citations related to engineering education is increasing and is expected to continue to grow. This study contributes to the literature by providing insights into this field by analyzing influential literature and research trends.

sustainability. Hence, researchers need to have a clear research map to assess the studies in engineering education research and follow the research trends to make their research more effective and present new knowledge to scholars. Bibliometrics is used increasingly in educational research to assess publications in a field. It helps researchers to quantitatively analyze research productivity in a field or research topic to understand the impact and visibility of research outputs.

Furthermore, bibliometric analyses contribute to identifying emerging trends, influential publications, and research networks (Ha et al., 2020). This approach provides a statistically sound overview of the value of writing systematic reviews. In addition, by conducting rigorous and thorough reviews, these studies provide a comprehensive overview of research trends and topics that can help practitioners and researchers improve knowledge and understanding in the field of education (Rojas et al., 2022). In addition, bibliometric analyses provide a structured overview of research and help identify emerging trends in education (Nandiyanto & Al Husaeni, 2022). Indeed, bibliometric studies are a valuable tool for understanding the landscape of educational research, mapping areas of knowledge, and assessing the impact and visibility of research findings. Some studies, such as Mamun et al. (2021), have used bibliometric analysis to assess research on engineering education. However, previous studies that analyze research trends in engineering education research through a bibliometric approach are limited. For example, Xian and Madhavan (2014) conducted a study to analyze research trends in engineering education. Their research was published nearly 10 years ago. Nandiyanto and Al Husaeni (2022) used only Google Scholar data and analyzed the period between 2017 and 2021. The study by Al Husaeni and Nandiyanto (2022) analyzed research on mechanical engineering education research from 2012 to 2021. A study by Saraf and Kumar (2023) analyzed a limited number of publications and examined only research on engineering education for sustainable development. Similarly, the study by Narong and Hallinger (2024) used the bibliometric method to analyze research on engineering education for sustainability. Additionally, the existing studies lack the systematic rigor required to represent the current research landscape accurately. Consequently, there is a noticeable absence of academic evaluations focused on determining global research's present status and progress in engineering education. Based on these findings, these studies are missing a gap in exploring research trends in engineering education research through bibliometric analysis. In addition, there has been a lack of analysis of research trends in engineering education using bibliometric analysis, including many publications in a prominent database such as the Scopus database over the past decade. This study fills the gap by conducting a bibliometric analysis to offer a thorough summary of research in engineering education from 2014 to 2023. Therefore, this study aimed to explore the research trends in engineering education through bibliometric analysis. This research aims to fill the current gap in knowledge regarding the state and development of research in engineering education. The results have the potential to provide better insights into the research trends and the field's growth. Our results from a bibliometric review can contribute to a deeper understanding of the field and its development.

REVIEW OF RELATED LITERATURE

Many researchers have attempted to identify emerging trends in engineering education over the past few decades (e. g., Nandiyanto & Al Husaeni, 2022; Saraf & Kumar, 2023; Xian & Madhavan, 2014). Researchers have indicated that bibliometric analysis is less constrained and more time-efficient than other review types (Vogel et al., 2021). Additionally, some researchers have utilized the bibliometric research method to analyze the current state of research on the most pressing topics in engineering education and determine their development level. From this aspect, bibliometric research in engineering education has provided valuable insights into the trends and focus areas of the field. For example, Williams et al. (2016) analyzed 4,321 publications, and they found that sources with the USA affiliations dominated citations in American Society of Engineering Education conferences. In contrast, data from the European Society of Engineering Education showed that while the USA sources are frequently cited, European and other authors are well represented. Xian and Madhavan (2014) conducted a study to examine the structure of scientific collaboration in engineering

education research. They analyzed 24,172 journal articles and conference proceedings from 2000 to 2011 using bibliometric and social network analysis. Their findings suggest that the engineering research community is in the early stages of building a small research network.

Karabulut-Ilgu et al. (2018) conducted a systematic review to describe the state of knowledge and practice of flipped learning in engineering education. However, their review did not use a bibliometric method. The researchers reviewed articles published from 2000 to May 2015, revealing that flipped learning gained popularity in engineering education after 2012. The review also revealed that research in engineering education primarily focused on documenting the design and development process, as well as sharing preliminary results and student feedback. The research of Mamun et al. (2021) applied a bibliometric approach to objectively map the research on flipped learning in engineering education, indicating the use of bibliometrics to provide a comprehensive overview of specific educational methodologies. They analyzed 106 articles from the Web of Science (WoS) between 2013 and 2020. They found that flipped learning in engineering education is a relatively new area that has experienced exponential growth in recent years. Nandiyanto and Al Husaeni (2022) study conducted a bibliometric analysis of engineering research articles indexed by Google Scholar. They analyzed articles published between 2017 and 2021. The results of their analysis indicate a decline in engineering research over the past five years. The number of articles published decreased from 396 in 2017 to 14 in 2021. They found that one of the most commonly researched areas in engineering is the field of engineering itself, while the environment is the least researched topic. Computer science is the area with the most relevant research concerning engineering-related keywords. Another study by Al Husaeni and Nandiyanto (2022) on mechanical engineering education research used bibliometric analysis and data from Google Scholar database publications from 2012 to 2021. The results showed fluctuations in publications in the last 10 years. The research decreased from 40 studies in 2019 to 11 studies in 2021. However, they found that the most popular research on mechanical engineering education was conducted in 2012. Al Husaeni et al. (2022) conducted a bibliometric to examine the impact of publications in the ASEAN Journal of Science and Engineering Education. They found that the journal's internationalization efforts facilitated the development of international collaboration networks, contributing to a broader range of research topics and a more diverse set of research outputs.

Qiu and Natarajarathinam (2023) analyzed the characteristics of publications published in the Journal of Engineering Education. They performed this analysis on the articles that the Scopus database indexed. Their findings showed that the contribution and influence of the Journal of Engineering Education in empirical engineering research is growing, both in terms of the number of published articles and their quality or citations. The majority of the institutions contributing articles were from the USA. In a study conducted by Ali and Tse (2023), they analyzed 142 journal articles from WoS database between 2011 and 2021 to understand the current research trends and topics in the engineering design process (EDP). The study found that the most important areas of research in EDP included professional development, design thinking, computational thinking, STEM skills, scientific research, and gender differences in STEM education. In their study, Saraf and Kumar (2023) aimed to provide bibliometric information on 1,995 included publications from the Scopus database. Their goal was also to produce a review of research on engineering education for sustainable development. The timeframe of their analysis was between 2010 and 2023. They found 2022 was not productive regarding publications on engineering education for sustainable development, especially compared to recent years. Narong and Hallinger (2024) recently conducted a bibliometric review to analyze the literature's research landscape and intellectual structure in engineering education for sustainability. The study included documents indexed by the Scopus database, published between 1991 and 2022. The review revealed a steady growth in research output and geographical diversity in this field. What is missing from the studies above is the exploration of research trends in engineering education research through bibliometric analysis. Xian and Madhavan (2014) conducted a study to analyze research trends in engineering education. Nandiyanto and Al Husaeni (2022) used only Google Scholars' data and analyzed between 2017 and 2021. The study of Al Husaeni and Nandiyanto (2022) analyzed research on mechanical engineering education research from 2012 to 2021. A study by Saraf and Kumar (2023) analyzed limited publications and reviewed only research on engineering education for sustainable development. Similarly, Narong and Hallinger's (2024) study used the bibliometric method to analyze the research on engineering education for sustainability. Based on these findings, it is obvious that there is a lack of research analysis of the research trends in engineering education research through bibliometric analysis, which involves a huge number of publications in one prominent database like the Scopus database over the last 10 years. Therefore, this study aimed to explore research trends in engineering education research through bibliometric analysis.

METHOD

A bibliometric analysis was conducted to study research trends and issues in engineering education. The data was collected from the Scopus database, covering

the period between 2014 and 2023. We chose the Scopus database because it contains important peer-reviewed journals in engineering education. Published by Elsevier, it is considered the world's leading literature database. The Scopus database also provides comprehensive coverage and metadata for scientific publications. Due to its extensive coverage and many research entries, we favored the Scopus database for sourcing research data. We used the keywords "engineering education," "engineering instruction," "engineering training," and "engineering teaching" in the title, abstracts, and keywords option to reach the related publications. No language limitation was used. The database was filtered to include only documents of the type "article." In addition, we limited the publications to the field of social sciences. A search led to the extraction of 6,338 articles used for the analysis. Later, bibliometric metadata were downloaded from the database in CSV file format. After this, CSV file format was transformed into a TAB-delimited file. Thus, the authors obtained the appropriate file for the bibliometric analysis. Among 6,338 articles, 6,196 articles were in English. Of the other articles, 82 were Russian, 31 in Spanish, 17 in Chinese, nine in Portuguese, four in Bosnian, three in Indonesian, two in Turkish, two in German, two in French, one in Norwegian, one in Japanese, one in Croatian, and one in Bulgarian.

Data Analysis

Bibliometric analysis involves quantifying data from research articles and analyzing their use of knowledge in published documents. VOSviewer helps draw collaboration networks and visually represent bibliometric mapping. Thus, this study analyzed the data using VOSviewer version 1.6.17. VOSviewer can be used to identify research clusters in publications examined by researchers. This kind of analysis presents hot topics and trends. In addition, cluster analysis in VOSviewer can be used to recognize research clusters, fronts, and hot topic issues according to years. Thus, cluster analysis allows researchers to understand better research clusters (van Eck & Waltman, 2017). First, the analysis function of the Scopus database website was used to collect data on the frequency of publications and citations in engineering education research. This study used two methods to identify the most prominent authors, institutions, countries, journals, and the authors' collaborative networks. The first method was frequency counting, and the second was co-authorship analysis using VOSviewer. Each node in the collaboration network diagram symbolizes an author, an institution, or a country. The node's size represents the number of publications, and its color signifies the cluster it is part of. We used to identify the most influential literature in engineering education by examining the frequently cited literature in the database. To better analyze and understand the most essential topics in engineering education research, we used co-authorship, co-occurrence, and citation analysis to identify related keywords and research trends in the articles. The cluster analysis focused on analyzing the keywords rather than the titles or abstracts of the articles. This analysis provided information about each cluster's size and the most significant keywords.

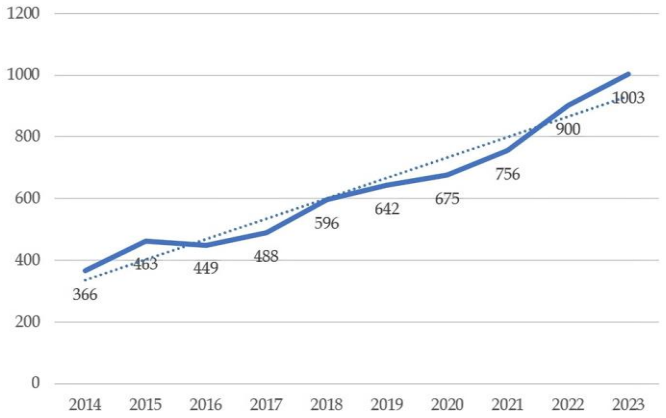

Figure 1. Trends in number of publications (Source: Authors' own elaboration)

Using high-frequency keywords can help to determine research trends effectively. High-frequency keywords indicate research areas or trends that are mentioned repeatedly every year. VOSviewer software allowed researchers to group the articles under a cluster using keywords. This helped to analyze and synthesize the research trends. The significance and originality of this study was that it examined the current state of engineering education research over 10 years using bibliometric methods, which deepened our understanding of engineering education.

RESULTS

Trends in Number of Publications

Between 2014 and 2023, trends in the number of publications on engineering education are shown in **Figure 1**. 6,338 articles in the database were found according to analysis criteria. As shown in **Figure 1**, the number of publications in engineering education research grew dynamically from 2014 to 2023. In **Figure 1**, the trendline represents an increase in the number of publications for the past 10 years in the research on engineering education.

In addition, as shown in **Figure 1**, the number of publications shows an increase in the number of publications according to years. The analysis showed that most studies on engineering education were published in the database in 2023, with 1003 articles. In 2022, 900 articles on engineering education were published. In 2021, while 756 articles were indexed on engineering education, this number was 675 in 2020. From 2015 to 2019, in previous years, the number of

Table 1. Top-10 authors according to number of articles & citations

Authors by number of articles				Authors by number of citations			
Authors	A	C	Institution	Authors	A	C	Institution
Gero, A.	21	213	Israel Institute of Technology	Tondeur, J.	8	1,406	Vrije Universiteit Brussel
Kolmos, A. J.	21	772	Aalborg University	Siddiq, F.	4	1,020	University of South-Eastern Norway
Borrego, M. J.	19	922	Cockrell School of Engineering	Scherer, R.	6	985	Info Universitetet i Oslo
Clark, R. M.	19	222	University of Pittsburgh	Borrego, M. J.	19	922	Cockrell School of Engineering
Magana, A. J.	18	374	Purdue Polytechnic Institute	Bower, M.	8	779	Macquarie University
Godwin, A.	17	435	Purdue University	Kolmos, A. J.	21	772	Aalborg University
Matusovich, H. M.	17	346	Virginia Tech	Callaghan, V.	1	539	University of Essex
Avsec, S.	15	138	Univerza v Ljubljani	Gardner, M.	1	539	University of Essex
Fang, N.	14	40	Utah State University	Guetl, C.	1	539	Graz University of Technology
Knight, D. B.	14	332	Virginia Tech	Jovanovic, C.	1	539	University of Belgrade

Note. A: Articles & C: Citations

research was 463, 449, 488, 596, and 642, respectively. In 2014, it was found that the least number of articles (n=366) were published in this year.

The results in **Figure 1** show a recession of research on engineering education between 2015 and 2017. After these years, the results show a constant increase in articles on engineering education from 2018 to 2023. This six-year period, from 2018 to 2023, and the 10-year decade show that research in engineering education has attracted increasing attention.

Most Contributing Authors

6,338 articles were found in the dataset between 2014 and 2023. It is crucial to recognize the authors who contribute the most to academic development, promote innovation, and strengthen engineering education research among many articles. The quantity of publications is a significant indicator of scientific research endeavors, directly reflecting the author's academic productivity.

For example, as **Table 1** shows, researchers including Aharon Gero, Anette Jepsen Kolmos, Maura J. Borrego, Renee M. Clark, Alejandra J. Magana, Allison Godwin, Holly M. Matusovich, Stanislav Avsec, Ning Fang, and David B. Knight, respectively, are the most prolific authors in the top-10 authors in the field of engineering education. This outcome suggests that these researchers have made a substantial contribution to the advancement of knowledge in this particular area. Regarding the number of citations, the results revealed that scholars such as Jo Tondeur, Fazilet Siddiq, Ronny Scherer, Maura J. Borrego, Matt Bower, Anette Jepsen Kolmos, Victor Callaghan, Michael Gardner, Christian Guetl, and Costa Jovanovi, are the authors that have the most citations. Particularly, the number of citations showed that scholars, including Victor Callaghan, Michael Gardner, Christian Guetl, and Costa Jovanovi, received 539 citations, although they had one publication in engineering education.

Another finding from **Table 1** is that seven of the top-10 authors with the most articles on engineering education are from the USA. The other three authors came from Denmark, Israel, and Slovenia. The authors with the highest citations are from Belgium, Denmark, Norway, Australia, the USA, the UK, Austria, and Serbia.

Figure 2 shows co-authorship analysis. We involved the authors who published more than five articles (n=221). The results revealed 13 clusters between authors, and 115 authors were found to have close relationships for co-authorship in the published articles.

The node size in **Figure 2** is directly proportional to the number of citations an author receives. Links between nodes indicate collaborations between authors.

Figure 2 shows that a few core authors had collaborated closely with other researchers who had published on engineering education, forming an academic research group. Another result is that there were connections between different research groups, indicating core authors who worked on engineering education, and limited interactions existed among some of those circles.

Most Contributing Institutions

Table 2 presents the institutions that have contributed the most to the research development on engineering education. The authors from the top-10 institutions published more than 50 articles.

The results in **Table 2** show that Purdue University and Virginia Tech University (Virginia Polytechnic Institute and State University) had the highest number of publications in the field. The other institutions that have the most publications included Universidad

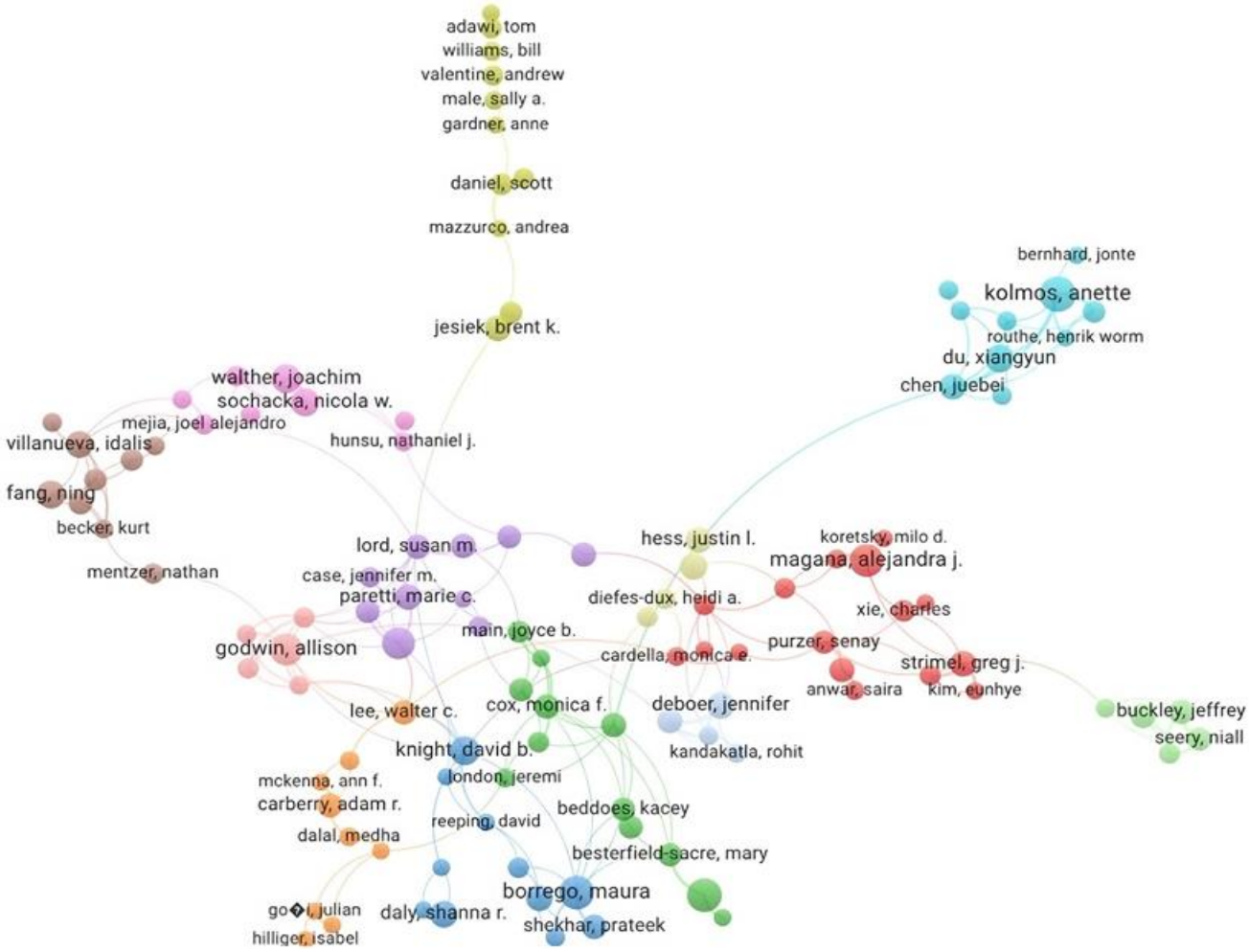

Figure 2. Co-authorship analysis among authors (Source: Authors' own elaboration, using VOSviewer 1.6.20)

Table 2. Institutions that have most articles & citations

Authors by number of articles				Authors by number of citations			
Institution	A	C	Country	Institution	A	C	Country
Purdue University	400	4,425	USA	Purdue University	400	4,425	USA
Virginia Tech University	193	4,031	USA	Virginia Tech	193	4,031	USA
Universidad Politécnica de Madrid	79	811	Spain	University of Michigan, Ann Arbor	65	1,352	USA
University of Michigan	65	1,352	USA	Aalborg University	63	1,381	Denmark
Aalborg University	63	1,381	Denmark	Virginia Tech Universtiy	63	1,299	USA
Texas A&M University	57	1,132	USA	Texas A&M University	57	1,132	USA
Utah State University	57	990	USA	Utah State University	57	990	USA
The Ohio State University	53	544	USA	Universidad Politécnica de Madrid	79	811	Spain
The Royal Institute of Technology	52	694	Sweden	Pennsylvania State University	49	716	USA
Pennsylvania State University	49	716	USA	The Royal Institute of Technology	52	694	Sweden

Note. A: Articles & C: Citations

Politécnica de Madrid, University of Michigan, Ann Arbor, Aalborg University, Virginia Tech College of Engineering, Texas A&M University, Utah State University, The Ohio State University, The Royal Institute of Technology, and Pennsylvania State University, respectively. The citation ranking reveals that most institutions on the list are located in the USA and only three from other countries, namely Aalborg University (Denmark), Universidad Politécnica de Madrid (Spain), and the Royal Institute of Technology (Sweden).

Regarding the institution with the most citations, results showed that Purdue University and Virginia Tech University had the highest number of citations.

Table 3. Countries that have most publications & citations

Countries by number of articles			Countries by number of citations		
Countries	Articles	Citations	Countries	Articles	Citations
USA	1,924	28,949	USA	1,924	28,949
China	543	3,927	UK	322	6,948
Spain	493	6,025	Australia	305	6,612
India	329	3,766	Spain	493	6,025
UK	322	6,948	China	543	3,927
Australia	305	6,612	Spain	493	6,025
Russian Federation	209	1,081	India	329	3,766
Sweden	188	2,502	Taiwan	142	2,739
Canada	168	2,327	Denmark	96	2,723
Türkiye	166	1,960	Netherlands	99	2,685

The other institutions are University of Michigan, Ann Arbor, Aalborg University, Texas A&M University, Utah State University, Universidad Politécnica de Madrid, Pennsylvania State University, and The Royal Institute of Technology. According to the results regarding the number of articles, seven institutions with the highest number of citations are from the USA. The other three countries are Denmark, Spain, and Sweden.

Most Contributing Countries

Table 3 shows the countries contributing most to engineering education research according to the results. The co-authorship analysis results for countries included 144 countries that published on engineering research, and we found that 72 countries had more than 10 papers.

The USA, China, and Spain were the top-three in the number of published articles. Between 2014 and 2023, authors from these countries have published over 150 articles. The top-10 countries were the USA, China, Spain, India, the UK, Australia, the Russian Federation, Sweden, Canada, and Türkiye.

The results revealed in **Table 3** demonstrate that the USA appears to be the leader in engineering education research and is a leading country in this field. The number of publications in the USA contains 41% of all publications. China, Spain, India, and the UK comprise 36% of the publications. The ranking mainly included countries from North America (the USA and Canada) and Europe (Spain, the UK, Sweden, and Türkiye), with additional countries from Australia, China, India, and Russia. The results with the number of citations by countries revealed that the USA is at the top. The USA, the UK, and Australia are the first three countries. Although Taiwan, Denmark, and the Netherlands are not on the list of countries with the most publications, they are among the top-10 countries with most citations.

Figure 3 shows the co-authorship analysis. The study findings indicate that the USA leads engineering

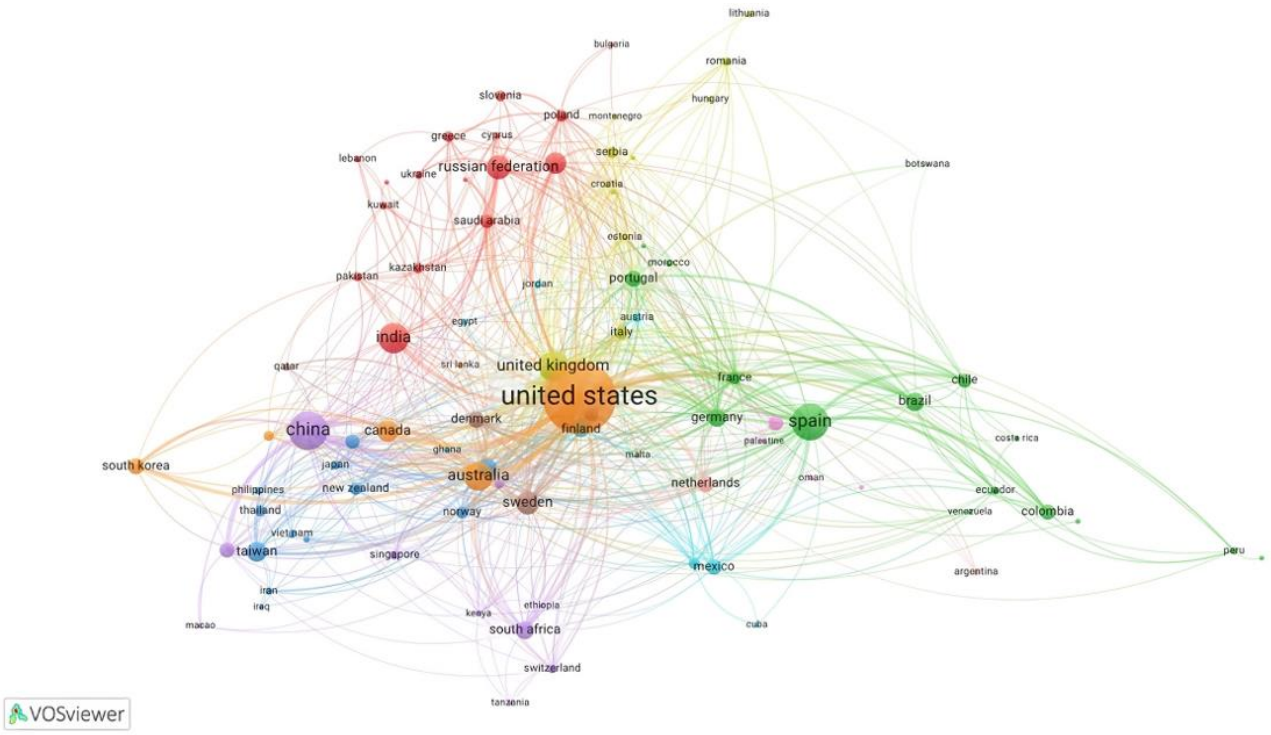

Figure 3. An analysis of co-authorship among countries (Source: Authors' own elaboration, using VOSviewer 1.6.20)

Table 4. Top-10 journals with highest number of publications

Journals by number of publications			Journals by number of citations		
Journal	NP	NC	Journal	NP	NC
International Journal of Engineering Education	748	4,315	Computers and Education	153	10,230
European Journal of Engineering Education	423	5,369	Journal of Engineering Education	224	7,212
Computer Applications in Engineering Education	347	4,001	European Journal of Engineering Education	423	5,369
International Journal of Emerging Technologies in Learning	283	2,200	International Journal of Engineering Education	748	4,315
IEEE Transactions on Education	244	3,243	British Journal of Educational Technology	135	4,064
International Journal of Technology and Design Education	236	2,547	Computer Applications in Engineering Education	347	4,001
Journal of Engineering Education	224	7,212	IEEE Transactions on Education	244	3,243
Journal of Engineering Education Transformations	201	289	International Journal of Technology and Design Education	236	2,547
Computers and Education	153	10,230	International Journal of Emerging Technologies in Learning	283	2,200
British Journal of Educational Technology	135	4,064	Internet and Higher Education	16	1,431

Note. NP: Number of publications & NC: Number of citations

education research and maintains connections with most countries, particularly Australia, Canada, Netherlands, South Korea, Sri Lanka, and the United Arab Emirates. In addition, China was closely connected with Ethiopia, Hong Kong, Kenya, Macao, Nigeria, South Africa, Singapore, Switzerland, and Tanzania. The results revealed that some countries were close to each other in co-authorship analysis among authors. The results also showed strong links with others, indicating strong connections among countries.

Most Contributing Journals

Citation analysis is commonly used in the bibliometric method to identify critical entities in a scientific field, such as authors, references, and sources or journals. Citation analysis assesses the frequency with which a unit is referenced by documents in the database under review. Highly referenced documents make substantial contributions to knowledge within a specific field. Within the last decade, many journals published articles investigating engineering education research. The results from bibliometrics revealed that 574 journals published at least one article on engineering education.

Table 4 lists the top-10 journals with the highest number of publications. Among all peer-reviewed journals, the International Journal of Engineering Education, the European Journal of Engineering Education, and Computer Applications in Engineering Education published more than 300 articles. Specifically, the International Journal of Engineering Education published 748 articles. The other journals included Computer Applications in Engineering Education, International Journal of Emerging Technologies in Learning, IEEE Transactions on Education, International Journal of Technology and Design Education, Journal of Engineering Education, Journal of Engineering Education Transformations, Computers and Education, and British Journal of Educational Technology.

Also, the results show that five journals in **Table 4** have focused on publishing articles on engineering education. The other five journals have published articles on education (e.g., IEEE Transactions on Education) and educational technology (e.g., British Journal of Educational Technology & Computers and Education). It can be concluded that these five journals have multiple categories due to their scope, which encompasses an interdisciplinary nature.

Another finding is that all the top-10 journals are related to education categories. In addition, these journals have continued their publishing lives for more than 10 years.

The journals' citation numbers show that Computers and Education have the most citations, although it published fewer articles on engineering education. The second journal with the most citations is the European Journal of Engineering Education. The third is the International Journal of Engineering Education. The following journals included the International Journal of Engineering Education, the British Journal of Educational Technology, Computer Applications in Engineering Education, IEEE Transactions on Education, the International Journal of Technology and Design Education, the International Journal of Emerging Technologies in Learning, Internet and Higher Education, respectively. Another finding is that although the journal "Internet and Higher Education" published only 16 articles, it received 1,431 citations.

Keyword Analysis & Research Trends

To understand a change in research, research trends facilitate examining fundamental knowledge areas in

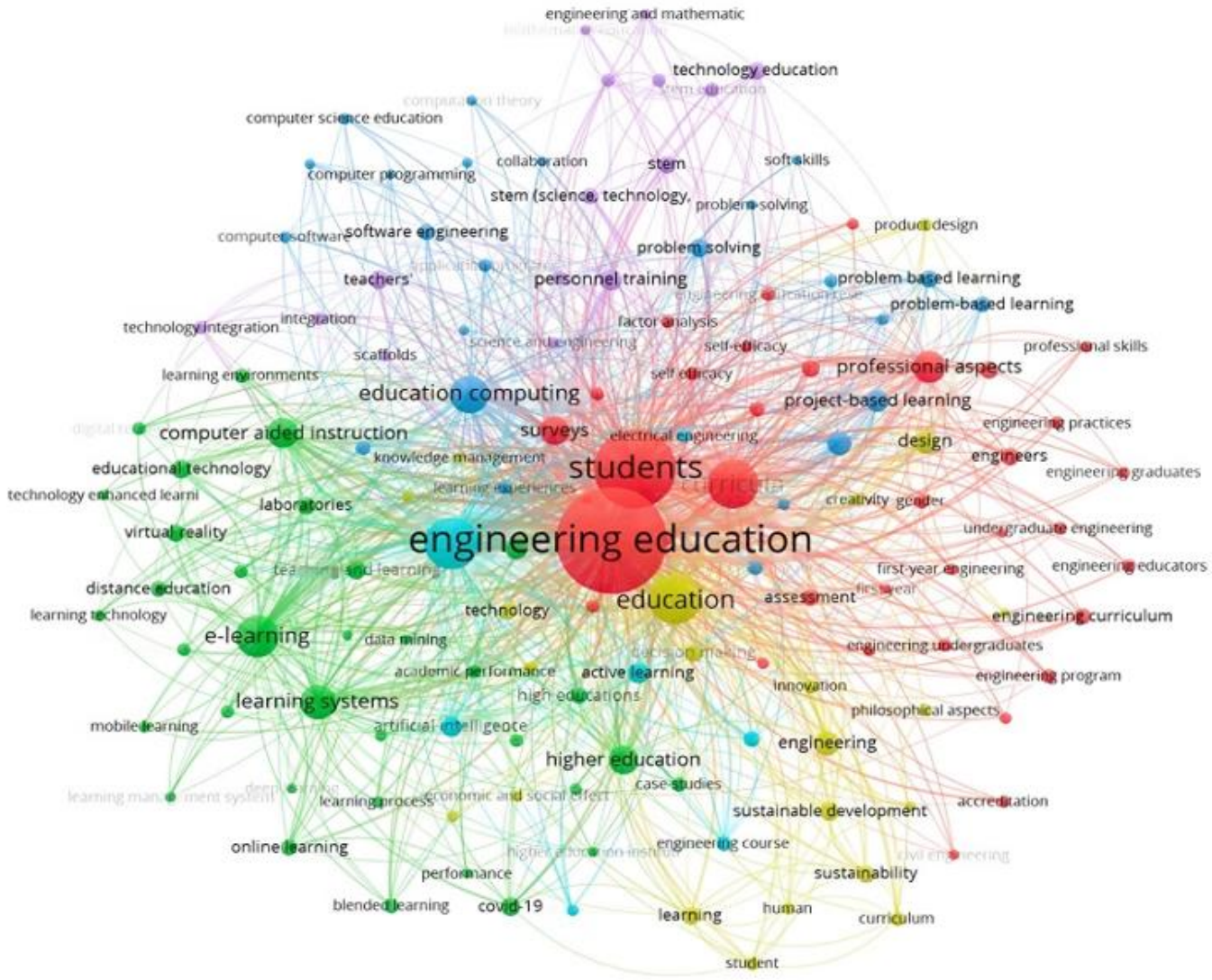

Figure 4. A mapping displaying co-occurrence of keywords from publications appearing together at least 50 times (n=138) (Source: Authors' own elaboration, using VOSviewer 1.6.20)

engineering education research. **Figure 4** displays research trends using keyword analysis in engineering education. In this study, results from VOSviewer software revealed six clusters.

Table 5 demonstrates six clusters revealed for research trends in engineering education research. Accordingly, the clusters and keywords in **Table 5** show the trends in engineering education research. Cluster 1 includes the keywords professional aspects 460, surveys 379, engineering design 151, self-efficacy 141, students' experiences and perceptions 121, assessment 111, engineering program 100, gender 93.

Based on these salient keywords in this cluster, it can be concluded that studies have focused on assessing students' professional aspects, views of engineering design, self-efficacy beliefs, and experiences and perceptions using quantitative data collection methods (surveys) in general. Assessing engineering students'

Table 5. Clusters of research trends in engineering education research

C	TK	Salient keywords
1	36	Professional aspects, surveys, engineering design, self-efficacy, students' experiences and perceptions, assessment, engineering program, & gender
2	34	Computer aided instruction, e-learning, learning system, higher education, motivation, & educational technology
3	24	Education computing, project-based learning, problem based learning, problem solving, & software engineering
4	22	Design, sustainable development, decision making, innovation, & product design
5	15	STEM, STEM education, personnel training, professional development, technology education, & technology integration
6	7	Teaching, active learning, artificial intelligence, technical presentations, & engineering course

Note. C: Cluster & TK: Number of total keywords

self-efficacy beliefs, experiences, and perceptions is essential due to its significant influence on achievement, persistence, and interest in the discipline (Hutchison et al., 2006). This study highlights the significance of students' professional aspects, engineering design views, self-efficacy beliefs, experiences, and perceptions as a research trend in engineering education.

Cluster 2 includes e-learning, the learning system, computer-aided instruction, higher education, motivation, and educational technology. Based on these salient keywords in this cluster, it can be concluded that studies have focused on using e-learning, learning systems, and computer-aided instruction in higher education in educational technology and engineering education. Also, this research has focused on examining the effects of learning, the learning system, and computer-aided instruction on students' learning outcomes like motivation at all levels. This result means that a line of research examines effects of educational technology practices on research participants' learning outcomes, such as motivation at all levels.

The most salient keyword in cluster 3 is "education computing." Project-based learning, problem-based learning, problem-solving, and software engineering are feature words in this cluster. The salient keywords in this cluster demonstrate a research trend in examining the effects of teaching methods such as project-based learning, problem-based learning, and problem-solving to enhance students' educational experience in computer science and related disciplines such as software engineering. Educational computing encompasses a broad range of efforts to enhance students' educational experience in computer science and related disciplines. This includes supporting educators in creating a cycle of teaching and computing education research (Brown et al., 2021). Educational computing is a multidimensional and evolving field encompassing various aspects such as pedagogical research, curriculum development, resource optimization, and integrating new technologies into education.

One important keyword that stands out in cluster 4 is "design." The other keywords that emerged as salient keywords are decision-making, sustainable development, innovation, and product design. The salient keywords in this cluster show a research trend in investigating and developing students' design skills, decision-making skills, and product design practices for innovative products for sustainable development. Cluster 5 included the keywords "STEM and STEM education." Later, personnel training, technology education, professional development, and Technology integration were found as salient keywords. This finding shows that the research in this line has focused on examining and developing personnel training, technology education, professional development, and Technology integration practices of engineering students in the context of STEM education. Cluster 6 included "teaching" as the most salient keywords. The other keywords included active learning, artificial intelligence 195, technical presentations, and engineering courses. Salient keywords in this cluster show that research has focused on teaching practices using artificial intelligence for technical presentations and engineering courses.

DISCUSSION

This study aimed to explore research trends in engineering education research through bibliometric analysis. Our results showed an increase in the number of publications in the research on engineering education for the past 10 years. The analysis showed that most studies on engineering education were published in the database in 2023, with 1,003 articles. The results also showed a recession of research on engineering education between 2015 and 2017. In general, the results revealed an increased tendency in engineering education research. This finding is similar to Qiu and Natarajarathinam's (2023), who found an increase in published articles and their quality or citations in engineering education research. On the other hand, these results are not similar to those of Saraf and Kumar (2023). They found 2022 was not productive regarding publications on engineering education for sustainable development, especially compared to recent years. The results regarding the top-10 authors revealed that seven of the top-10 authors with the most articles on engineering education are from the USA. The other three authors came from Denmark, Israel, and Slovenia. The co-authorship analysis results revealed 13 clusters between authors and that a few core authors had collaborated closely with other researchers who had published on engineering education. Core authors had formed academic circles with slight connections between research groups.

The citation ranking is dominated by institutions from the USA, with only three from other countries (Denmark, Spain, and Sweden). Regarding the institutions with the most citations, the results showed that seven institutions with the most citations are from the USA. The other three countries are Denmark, Spain, and Sweden. The co-authorship analysis showed that the top-10 countries were the USA, China, Spain, India, the UK, Australia, the Russian Federation, Sweden, Canada, and Turkey. The study suggests that the USA, China, Spain, India, and the UK are leading in research on engineering education. Several factors could explain this finding. Firstly, the number of articles published in English can be higher than in other languages. Secondly, another reason may be that engineering education policies in these leading countries can be very active. Also, the results show that the USA appears to be the leader in engineering education research and is a leading country in this field. The results of Qiu and

Natarajarathinam (2023) analyzed the characteristics of publications published in the Journal of Engineering Education to confirm our results. They found that most institutions contributing articles in engineering education were from the USA. Particularly, due to several key factors, the USA is a leading country in engineering education research. First, the country has seen the emergence of doctoral-granting departments in colleges of engineering, such as Purdue and Virginia Tech, and the establishment of centers for engineering education research (Singer & Smith, 2013). In addition, the USA is a top destination for foreign talent in science and engineering doctoral education due to the attractiveness of better educational opportunities and financial support (Tanyildiz, 2013). Similarly, the USA is also at the forefront of promoting STEM education (Cheng, 2023). In addition, the engineering profession in North America has called for greater leadership responsibility in the workplace and the inclusion of leadership skills in engineering education (Li et al., 2022). In addition, the USA has a rigorous research in engineering education (Borrego, 2007). The country has also published and disseminated scholarly works on engineering education that focus on teaching and research (Borrego et al., 2008). These pieces of evidence show that the USA is a leader in engineering education research because it proactively establishes doctoral-granting departments, attracts foreign talent, emphasizes professional skills development, promotes STEM education, and supports rigorous research in engineering education.

Results regarding the top journals that have the highest number of articles on engineering education demonstrated that five journals are the journals that publish articles specifically on engineering education. The other five journals have published articles on education and educational technology. A reason for this result can stem from the fact that these journals have continued their publishing lives for more than 10 years. The citation performance of journals, especially in engineering, has been shown to affect their visibility, with highly cited journals receiving more attention and recognition in the academic community (Lukman et al., 2018).

Regarding research trends, our results produced six clusters to explain the research trends in engineering education research. Cluster 1 included professional aspects, surveys, engineering design, self-efficacy, students' experiences and perceptions, assessment, engineering program, gender. Based on these salient keywords in this cluster, it can be concluded that studies have focused on assessing students' professional aspects, views of engineering design, self-efficacy beliefs, and experiences and perceptions using quantitative data collection methods (surveys) in general. First, engineering students' self-efficacy beliefs, experiences, and perceptions have a significant influence on their achievement and interest (Hutchison et al., 2006). Self-efficacy beliefs are critical to students' success in engineering education (Concannon & Barrow, 2012; Hutchison-Green et al., 2008). Second, students' perceptions of the engineering profession, ethical beliefs, and understanding of engineers' work can influence their career aspirations and decisions (Binani, 2022; Ergun & Balcin, 2019). In addition, students' perceptions of engineering excellence and their understanding of the profession are important to determine and increase their interest (Pomales-Garcia & Liu, 2007; Towers et al., 2011). Moreover, students' perceptions foster their interest in having a career in engineering (Sulaiman et al., 2020).

Cluster 2 includes the keywords e-learning, the learning system, computer-aided instruction, higher education, motivation, and educational technology. Based on these salient keywords in this cluster, it can be concluded that studies have focused on using e-learning, learning systems, and computer-aided instruction in higher education in educational technology and engineering education. Also, this research has focused on examining the effects of learning, the learning system, and computer-aided instruction on students' learning outcomes, such as motivation at all levels. This result means that a line of research examines the effects of educational technology practices on the research participants' learning outcomes, such as motivation at all levels. One reason for this result may be that educational technology can present interactive and engaging learning experiences for students. In addition, the potential of e-learning as an educational system for engineering subjects has been emphasized by researchers (Abumandour, 2021). Furthermore, integrating computer-assisted learning and simulation technologies into undergraduate engineering courses has been studied mostly (Vatansever & Yalcin, 2017).

The most salient keyword in cluster 3 is "education computing." Project-based learning, problem-based learning, problem-solving, and software engineering are feature words in this cluster. The salient keywords in this cluster demonstrate a research trend in examining the effects of teaching methods such as project-based learning, problem-based learning, and problem-solving to enhance students' educational experience in computer science and related disciplines such as software engineering. Educational computing encompasses a broad range of efforts to enhance student's educational experience in computer science and related disciplines. Educational computing encompasses many efforts to enhance students' educational experience in computer science and related disciplines. This includes supporting educators in creating a cycle of teaching and computing education research (Brown et al., 2021) and understanding the predictors of attitude toward applying computer-supported education (Yesilyurt et al., 2016). Additionally, it involves integrating

computational thinking into computing education. Furthermore, educational computing involves analyzing the current state of information in education, reviewing and using learning theories within computer science education research (Szabo et al., 2019), and exploring international trends in K-12 computer science curricula (Oda et al., 2021).

The most salient keyword in cluster 4 is "design." The other keywords that were revealed as salient keywords are decision-making, sustainable development, innovation, and product design. The salient keywords in this cluster demonstrate a research trend in examining and developing students' design skills, decision-making skills, and product design practices for innovative products for sustainable development. Cluster 5 included the most keyword of "STEM and STEM education". Later, personnel training, technology education, professional development, and Technology integration were found as salient keywords. This finding shows that the research in this line has focused on examining and developing personnel training, technology education, professional development, and Technology integration practices of engineering students in the context of STEM education. Cluster 6 included "teaching" as the most salient keywords. The other keywords included active learning, artificial intelligence 195, technical presentations, and engineering courses. Salient keywords in this cluster show that research has focused on teaching practices using artificial intelligence for technical presentations and engineering courses.

Limitations

This study has some limitations. First, we only utilized articles from the Scopus database. Second, the effectiveness of the bibliometric method may be limited by the researcher's skill to anticipate and include all relevant terms, including synonyms and homonyms, which may affect the completeness of the data. Therefore, the keywords researchers use to examine topics or trends in a specific discipline may affect the results. Third, we examined articles published in the last 10 years in this study. Fourth, this study only focused on the articles published in academic journals. Fifth, another point to note is that the visualization software VOSviewer was used in this study. However, other software could be used for further analysis to produce more comprehensive results based on the same field.

CONCLUSIONS

This study aimed to explore research trends in engineering education research through bibliometric analysis. The results showed that engineering education has experienced consistent growth over the last 10 years. Its development has been accelerated by leading countries, institutions, journals, and researchers who have significantly contributed to creating and accumulating knowledge. Scientists from North America, Europe, Australia, and Asia were more involved in research and collaborated frequently. However, researchers from countries in South America, the Middle East, and Africa had limited contributions to scientific literature. The findings suggest that researchers in this field have explored several subjects, with six clusters standing out prominently. For example, Cluster 1 assessed self-efficacy beliefs, experiences, and perceptions of engineering education programs or degrees. Cluster 2 focused on the effects of education technology practices such as e-learning, learning systems, and computer-aided instruction on learning outcomes like motivation in higher education. Cluster 3 demonstrated a research trend in examining the effects of teaching methods such as project-based learning, problem-based learning, and problem-solving to enhance students' educational experience in computer science and related disciplines such as software engineering. Cluster 4 demonstrates a research trend in examining and developing students' design skills, decision-making skills, and product design practices for innovative products for sustainable development. Cluster 5 focused on examining and developing personnel training, technology education, professional development, and Technology integration practices of engineering students in the context of STEM education. Cluster 6 included research on teaching practices using artificial intelligence for technical presentations and engineering courses. The number of publications and citations related to engineering education is rising and is expected to continue to increase. This study has provided insights into this by analyzing highly influential literature and research trends. Firstly, since formal education plays a vital role in engineering education, STEM teachers should pay more attention to the issues that arise in schools and classrooms. Based on the results from this study, the emphasis on self-efficacy beliefs, experiences, and perceptions related to engineering majors or degrees demonstrates the importance of students' beliefs, experiences, and perceptions in pursuing careers in engineering fields. Scholars emphasize that the skill of scientific argumentation is very important in developing students' views about the nature of science and the nature of engineering. In particular, socio-scientific issues have become increasingly important for developing students' reasoning skills and views on science, technology, and society.

RECOMMENDATIONS

Several recommendations can be derived from the data of this study. First, integrating systematic reviews and bibliometric results can yield promising results to for further research based. Thus, future research can incorporate quantitative and qualitative methods to

have more holistic understanding about the status of research. In addition, future research can significantly improve results from a bibliometric study by adding more detailed results from a qualitative analysis.

Furthermore, researchers in future research should consider to include comparative studies from different databases or longitudinal studies with longer periods, multiple databases, or article types. To conduct more comprehensive studies, future research could expand the scope of the selected literature and other bibliometric software in the future.

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