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Review Article

Uncovering patterns and trends in online teaching and learning for STEM education

Muslimat G. Akhmedova [1*]
0000-0002-0160-7010

Gasangusein I. Ibragimov [2]
0000-0002-3506-0754

Nina I. Kryukova [3]
0000-0002-0667-9945

Natalya A. Galchenko [4]
0000-0002-1717-5101

Larisa Y. Lutskovskaia [5]
0000-0002-4806-6610

Zhanna M. Sizova [6]
0000-0002-1242-7074

Marat R. Minkin [7]
0000-0002-1196-8143

[1] Financial University Under the Government of the Russian Federation, Moscow, RUSSIA
[2] Kazan (Volga Region) Federal University, Kazan, RUSSIA
[3] Plekhanov Russian University of Economics, Moscow, RUSSIA
[4] Murmansk Arctic State University, Murmansk, RUSSIA
[5] Peoples' Friendship University of Russia, Moscow, RUSSIA
[6] Sechenov First Moscow State Medical University, Moscow, RUSSIA
[7] Almetyevsk State Oil Institute, Almetyevsk, RUSSIA
[*] Corresponding author: muslima11@rambler.ru

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ABSTRACT

This article provides a bibliometric overview of publications on eLearning trends in STE(A)M teaching and learning to give readers a better understanding of the current state of research in the field. The main objective of this study is to provide bibliometric data on publications on online teaching and learning trends for science, technology, engineering, and mathematics education (STEM) teaching and learning purposes printed in journals included in the Scopus database in the years 2011-2023. For the bibliometric analysis, STEM learning, STEM teaching, online education, bibliometric review keywords were used, and 136 documents from the Scopus database were chosen. The collected data of the publications scanned and published in the parameters of the study were subjected to a bibliometric analysis based on seven categories: number of articles and citations per year, most influential countries, most prolific author, most prominent affiliations, funding institutions, publication source, and subject areas. Network diagrams and bibliometric analyses were created using the Scopus database analysis. Most of the articles were published between 2016 and 2022. The United States of America, the United Kingdom, and China were among the top-three most productive countries, and the United States of America produced the most publications. The number of citations to publications indexed in the Scopus database is growing steadily and reached its peak in 2022 (178 citations). The most prolific author on this subject is Minichiello, A., with four publications. In addition, Stanford

University and Utah State University have maximum publishing partners. By funding 16 publications for online STEM teaching and learning, the National Science Foundation has shown leadership. The topic areas of the publications' distribution were looked at. The articles' respective fields of study were social sciences and computer science. This study offers a vision for future research as well as a worldwide view of online learning for STEM teaching and learning.

Keywords: STEM learning, STEM teaching, online education, bibliometric review

INTRODUCTION

Particularly in science, technology, engineering, and mathematics education (STEM), online learning has grown quickly in recent years. Numerous developments in technology, shifting paradigms in teaching and learning, and rising demand for flexible and accessible education are just a few of the causes of this growth (Singh et al., 2005). Numerous scholars have done bibliometric reviews to examine the trends and patterns in online STEM teaching and learning (Gamage et al., 2022; Gao et al., 2022; Jamali et al., 2022; Kundu et al., 2022; Maphosa et al., 2022; Ozkaya, 2019; Su & Yang, 2023; Sudakova et al., 2022; Sudrajat et al., 2022; Talan, 2021; Tas & Bolat, 2022).

In the past 10 years, there have been a lot more publications about online learning in STEM education, according to a study by Le Thi Thu et al. (2021). According to the authors' analysis of 840 papers from the Scopus database, there were 239 publications in 2018 compared to 49 in 2009, for a compound annual growth rate of 13.80%. An additional study by Bozkurt et al. (2019) discovered a comparable pattern, with a notable rise in publications pertaining to online learning in STEM education from 2014 to 2016.

Understanding the trends and patterns in this field is essential given the growing acceptance of and significance of online learning in STEM education. By emphasizing important themes and flagging gaps in the existing body of information, this bibliometric review attempts to give a thorough overview of the literature on online learning in STEM teaching and learning.

We conducted a systematic search of the Scopus database using a set of predetermined search phrases linked to online learning and STEM education to achieve this purpose. Then, using inclusion criteria, we screened and selected relevant articles, which included peer-reviewed articles published between 2011 and 2023, written in English, and focused on online learning in STEM education. Following the screening process, we identified 136 articles that met our inclusion criteria. These papers were then subjected to bibliometric analysis, which included number of articles and citations per year, most influential countries, most prolific author, most prominent affiliations, funding institutions, publication source, and subject areas in order to discover major themes, trends, and patterns in the literature.

The findings of this bibliometric evaluation are anticipated to offer precious insights into the modern-day nation of studies on online mastering in STEM education and assist in future studies and exercises in this area (Samara & Kotsis, 2023; Zakeri et al., 2023). Specifically, this evaluation will contribute to the identification of key study gaps and the improvement of powerful techniques for designing and implementing on-line STEM education.

Our literature review identified several key trends in online STEM teaching and learning. These included the use of learning management systems (LMS) and course management systems (CMS) such as Moodle (AL-Nuaimi et al., 2022; Raman et al., 2022), the development of online STEM courses and programs in various formats (Liu et al., 2020; Megri et al., 2021), and the use of educational technologies such as artificial intelligence (AI) and virtual reality (VR) (Hwang & Chien, 2022; Yin, 2022). It was also found a growing interest in the design and evaluation of online STEM courses and programs (Baran et al., 2019; Garrison & Akyol, 2015; Kier et al., 2014).

METHODOLOGY

Data Collection Process

It was conducted a search on the Scopus database using keywords such as "STEM or STEAM education" and "online education" or "online learning" or "online teaching". We selected publications between 2011 and

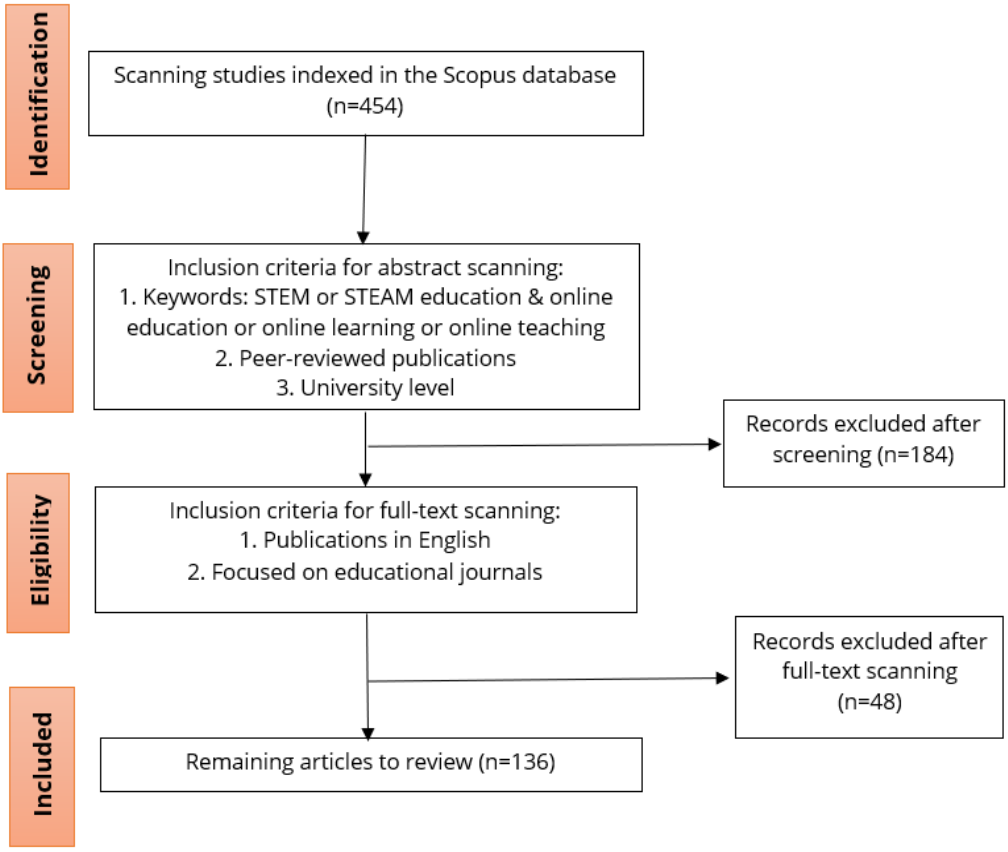

Figure 1. Article selection process based on PRISMA flow diagram (Source: Authors)

2023 and focused on those related to online learning trends in STEM education. In the first scan, 454 publications were found, and 270 publications remained after educational context and journals were selected. After selecting peer-reviewed English-language publications, the search yielded 136 publications, which were analyzed using bibliographic methods. The article selection process followed preferred reporting items for systematic reviews and meta-analyses (PRISMA) standards (Moher et al., 2015) (**Figure 1**).

Data Analysis

Excel and Scopus Analyzer were two of the bibliometric tools used to analyze the data and create maps of important factors. In the study, statistical analysis was also done to look for trends and patterns in the data. Descriptive statistics were used to analyze the distribution of publishing output across yearly accounts, nations, publications, and publication years. To determine whether there were any notable differences in publishing output between different factors, inferential statistics were also used.

The scope of the search, which only included publications indexed in the Scopus database, limited the scope of the study. Furthermore, the study was limited by the lack of some other bibliometric data such as number of citations by author and affiliations. Despite these limitations, the study provided valuable insights into trends in online learning research for STEM teaching and learning published in journals indexed in the Scopus database.

RESULTS

Publications Distribution by Type and Year

Most of the publications (49.26%) were articles, while 38.23% were conference papers. The remaining 12.51% were reviews, book chapters, and conference reviews, etc. according to **Figure 2**. One explanation for this is because STEM and online education is a popular research topic for many years in science education.

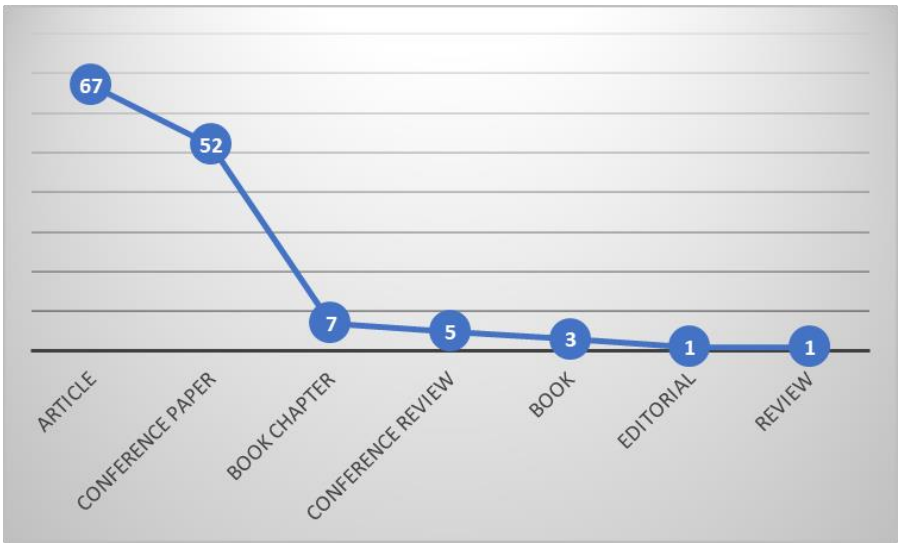

Figure 2. Number of documents by type (Created using Excel software based on study data)

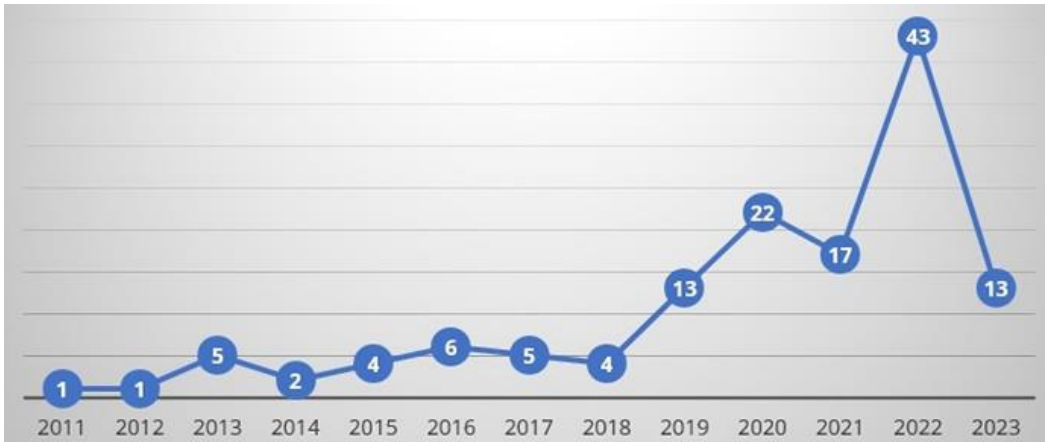

Figure 3. Number of documents by year (Created using Excel software based on study data)

In the study, the distribution of the publications by year in the journals included in the Scopus database was initially examined. The study's findings are displayed in **Figure 3**. **Figure 3** showed that although there were fewer publications between 2011 and 2018, there was an increase in those numbers in the subsequent years. However, most of all articles are found in publications that were published after 2018. The two years with the highest number of publications were 2022 (f=43) and 2020 (f=22).

Publications by Country Distribution

The distribution of the discipline's publications by nations was also examined. Top-10 nations by number of publications are shown in **Figure 4**. According to **Figure 4** (f=59), most of the documents were completed in the United States of America. China (f=8), the United Kingdom (f=7), Greece and Russian Federation (f=5), Australia, Canada, Germany, South Africa, and Spain (f=4) and other countries were listed after the list.

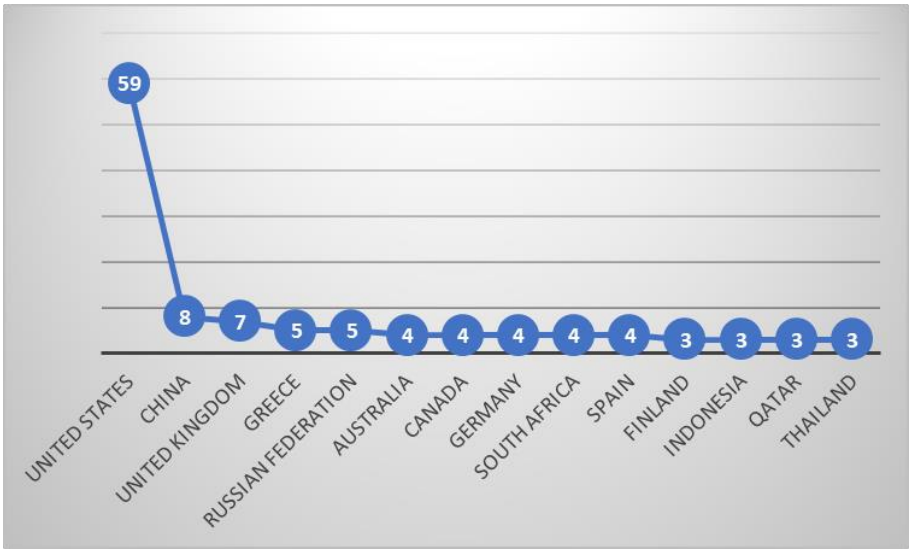

Figure 4. Number of documents by country (Created using Excel software based on study data)

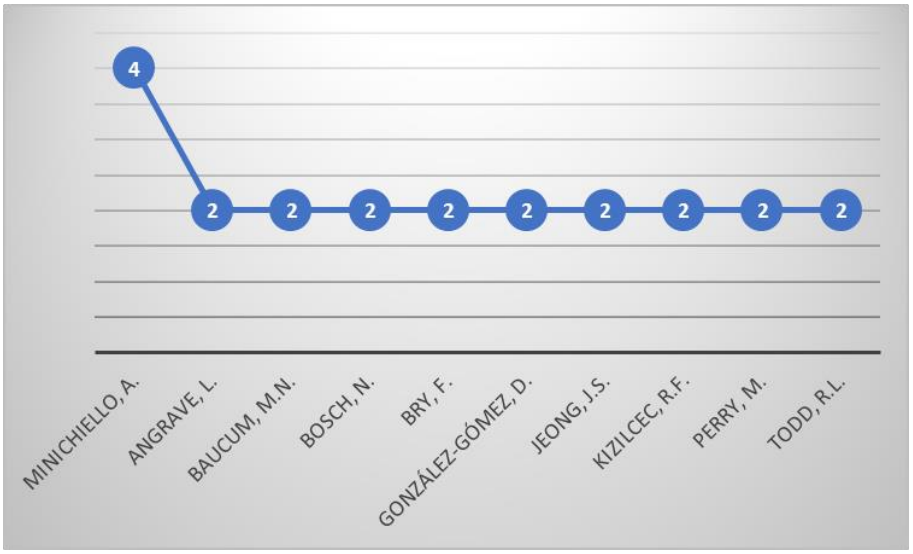

Figure 5. Number of publications by author (Created using Excel software based on study data)

Number of Publications by Author

The authors published most of the documents related to online learning research for STEM teaching and learning were examined and Minichiello, A., was leader with four documents. All other authors are included in this ranking with two studies each (**Figure 5**).

Distribution Related to Number of Citations Per Year

Figure 6 demonstrates the steady rise in citations for studies related to online learning research for STEM teaching and learning throughout time. It is projected that fewer citations will be made in 2023 than in 2022 because the year has not yet ended. Additionally, it can be seen that in 2022, the number of citations for studies related to online learning research for STEM teaching and learning reached its peak.

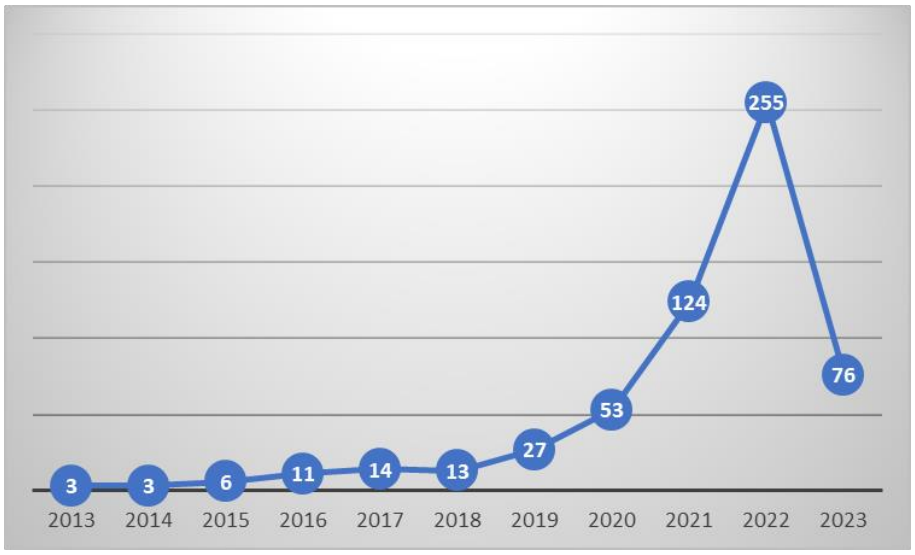

Figure 6. Number of citations per year (Created using Excel software based on study data)

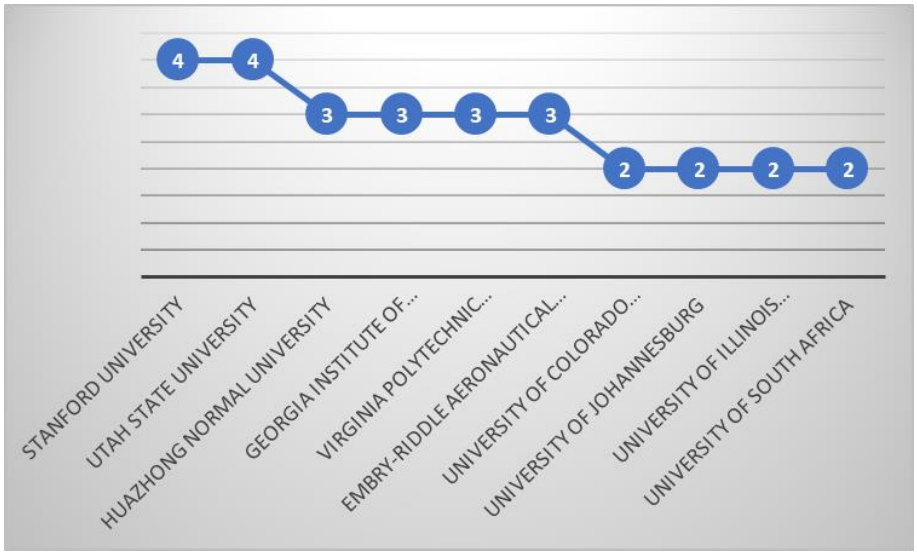

Figure 7. Number of documents by affiliation (Created using Excel software based on study data)

Distribution Related to Number of Publications by Affiliation

Stanford and Utah State Universities were the first with four publications each as can be seen from **Figure 7**. Moreover, Huazhong Normal University, Georgia Institute of Technology, Virginia Polytechnic Institute and State University, and Embry-Riddle Aeronautical University shared second ranking with three publications each. Finally, University of Colorado Boulder, University of Johannesburg, University of Illinois Urbana-Champaign, and University of South Africa shared third ranking with two publications each.

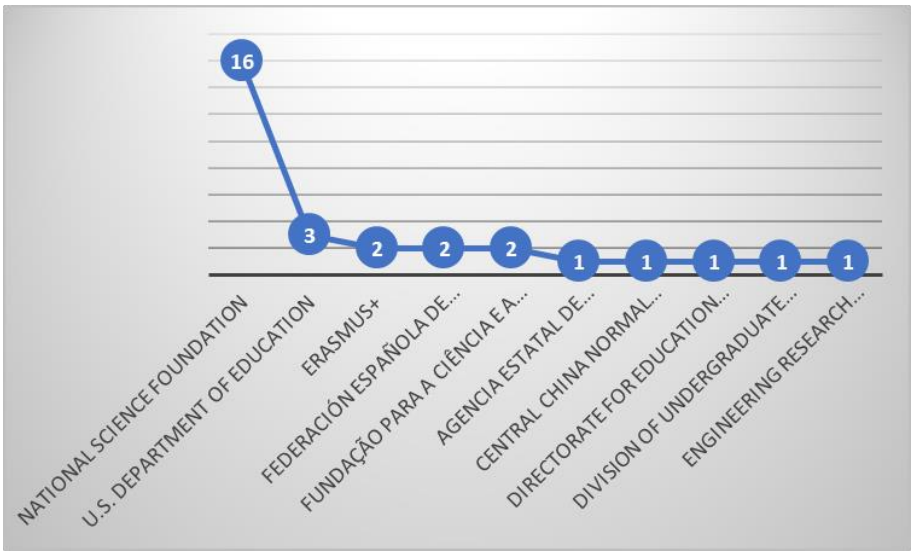

Figure 8. Number of documents by funding sponsor (Created using Excel software based on study data)

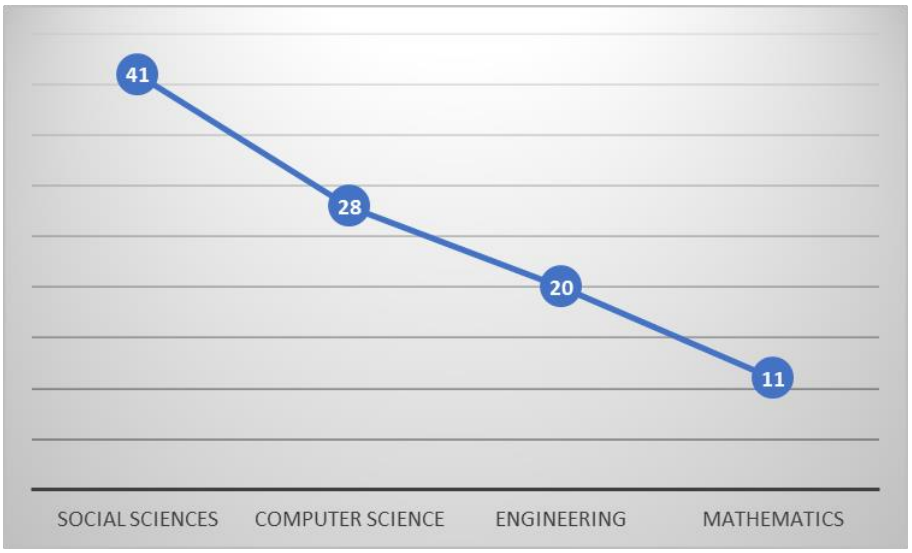

Figure 9. Number of documents by subject area (Created using Excel software based on study data)

Distribution in Terms of Number of Documents by Funding Sponsor

National Scientific Foundation demonstrated leadership by supporting 16 publications related to such a popular research topic entitled online learning for STEM teaching and learning according to **Figure 8**. The second-ranked funding sponsor was the United States of America Department of Education with three publications. Following that, there are three funding sponsors, each with two publications, and five additional sponsoring organizations, each with one publication.

Distribution Related to Number of Documents by Subject Area

Figure 9 shows that most of the studies (47.00%) are in the social sciences, 28.00% in the computer sciences, 24.00% in engineering education, and the remaining 7.00% in the mathematics education with regard to the subject areas of the publications.

DISCUSSION

136 publications on online STEM education were found in the Scopus database. The majority of the publications were published between 2019 and 2023, with a noteworthy rise starting in 2020. This finding is consistent with previous studies (Ahmed et al., 2023; Chen et al., 2021; Zhang et al., 2022). The United States

of America, China, and the United Kingdom were the top three most prolific countries with the most publications similar to the research done by Ha et al. (2021). The number of citations to publications in the Scopus database peaked in 2022 with 255 citations. This outcome is similar with the research done by Chu et al. (2023). Minichiello, A., who published four times, was the most productive author on this subject. The most publications are affiliated with Stanford and Utah State Universities. By number of articles published, National Science Foundation was the top funding source. It was examined how the publications were distributed by subject area. The publications' respective topic areas were social and computer sciences.

Our analysis confirms that online learning is gaining popularity and significance in STEM education. Although it has the potential to improve student outcomes, more research and development are needed to overcome the challenges associated with this mode of delivery.

The study uncovered that online STEM education research is dominated by the United States, China, and the United Kingdom. These heavyweights invest prolifically in STEM education and boast a significant number of STEM students. Moreover, the study highlights a shift towards blending e-learning with traditional classroom teaching rather than abandoning it entirely. This bibliometric review looks at how online learning has impacted STEM education over the past decade by analyzing research output, publication trends, and citation patterns in literature. This study also has revealed that there has been a surge in research publications related to this topic, highlighting its significance. The publications have varied interests, covering topics such as the use of online technologies for better STEM instruction, developing online curricula, and studying how online learning enhances student performance and engagement.

Our bibliometric assessment of the literature shows that online getting to know has come to be a vital part of STEM coaching and getting to know, and that there's a need for additional studies and improvement in this area. We advocate that destiny studies pay attention to the design, improvement, and assessment of online STEM publications and programs, in addition to the mixing of rising instructional technology with AI and VR. Because the COVID-19 pandemic has accelerated the adoption of online learning, it is likely that its importance in STEM education will only grow.

The bibliometric analysis of the trends in online education for STEM teaching and learning, in conclusion, offers insightful information about the present status of research in this area. The research reveals major themes and patterns in the literature and draws attention to the growing popularity of online learning for STEM courses. The limits of this bibliometric analysis must be acknowledged, and suggestions for further study should be made. Firstly, the bibliometric survey is based on existing published writing, which may present biases characteristic of the determination and accessibility of articles. It is significant for the future to consider joining other sources of information, such as conference procedures, unpublished research, and dark literature, to supply a more comprehensive understanding of the field. The study's second main focus is quantitative analysis, with particular attention paid to authorship patterns, publishing trends, and citation networks. Although these measurements offer useful information, they do not adequately reflect the subtleties and qualitative elements of online STEM learning. To better understand the experiences, viewpoints, and results of online learning in STEM education, future research should use qualitative techniques, including interviews, questionnaires, and case studies.

The review also primarily concentrates on research that has been published as of the present, which could not reflect the most recent developments and developing trends in online STEM learning. In order to capture the continuously changing landscape of this discipline and guarantee the relevance and currency of the findings, it is crucial for future research to undergo frequent updates.

In summary, our literature overview gives insights into the current developments in online mastering for STEM coaching and mastering. Further studies are wanted to completely apprehend the capacity of online mastery in STEM education, and to increase powerful techniques for its implementation.

CONCLUSIONS AND IMPLICATIONS

The study's conclusions show that online STEM education research publications are trending upward. Learning analytics, intelligent tutoring, gamification, virtual and augmented reality, and online laboratories

are some of the research themes that were found in the study. The most popular publications in this field and top contributor are also listed in the study.

The study's implications suggest that online STEM instruction is an area that is continuing to gain attention and investment from the intellectual community. The use of technology in STEM instruction can enhance scholars' literacy skills by furnishing interactive and engaging literacy environments. The effects of this study could serve as a companion for savants and experimenters in relating online STEM instruction.

After conducting an extensive bibliometric review on trends in online learning for STEM teaching and learning, it has become evident that there is a rising inclination toward the implementation of e-learning platforms like Moodle in STEM education. Our bibliometric review has also recognized the growing attention given to promising AI technology and its ability to revolutionize how students learn and instructors teach these subjects.

The educational and societal implications of the study are considerable, impacting educators, policymakers, and researchers alike. As e-learning platforms and technology continue to evolve at a rapid pace, it is of paramount importance that we have a sound comprehension of how these tools can optimize teaching and learning within STEM education. The COVID-19 pandemic has also reaffirmed this need, as many institutions globally have had to make a swift transition towards online learning. Consequently, the findings from our research lend valuable insight into not only the current climate but also emerging trends in online STEM education. These critical observations will support policymakers in developing sound policies geared towards enhancing the quality and accessibility of e-learning opportunities within STEM education.

Finally, the bibliometric analysis reveals that online STEM education is becoming more popular. The research trends, number of articles and citations per year, most influential countries, most prolific author, most prominent affiliations, funding institutions, publication source, and subject areas in this subject were determined by the study. The study's findings have significance for both researchers and practitioners, emphasizing the necessity of incorporating educational technology into STEM education to improve learning outcomes.

Future research should examine STEM subfields (e.g., physics, chemistry, biology, and computer science) for distinct challenges, pedagogies, and technological advancements. This would offer specific insights for STEM educators and policymakers on online learning.

In summary, future research must address the limitations identified in the bibliometric review of online STEM education. Researchers can deepen their understanding of online learning in STEM education by expanding data sources, incorporating qualitative methods, staying updated with advancements, and focusing on specific STEM subfields to develop effective pedagogical strategies and technologies for the future.

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Declaration of interest: Authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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