Research

Bibliometric and content analysis of meta-analysis studies in STEM education

Emine Kahraman [1]

Abstract:

The research aims to analyse the most current (2015-2023) literature on STEM education to gain a deeper understanding of current trends, priorities and developments in the field of STEM education. Scientific studies determined within the scope of the study were examined using bibliometric and content analysis methods, which are among the systematic compilation methods. First, access to the WoS database was gained, and a subject-based search was conducted using the keywords "STEM education" and "Meta-analysis." In this context, 38 scientific studies containing these relevant keywords were found in the search. The collected data were initially analyzed on the basis of descriptive attributes in the WoS. Subsequently, the listed publications were analyzed using the bibliometric analysis tool VOSviewer for bibliographic attributes, including citation counts, co-citation, co-authorship, co-occurrence, and bibliographic coupling analysis types, based on authors, institutions, and countries. Finally, 18 articles from these scientific publications were evaluated through content analysis in terms of various characteristics of following the PRISMA flowchart. The most prominent keywords associated with the examined concepts included technology-related terms like "computer-based learning," "digital game-based learning," "academic achievement," "active learning," and "problem-centered instruction." Furthermore, the general focus of scientific studies appears to be on determining the impact of a STEM education method on student performance.

Keywords: STEM education, meta-analysis, bibliometric analysis, content analysis

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INTRODUCTION

Scientific and technological advancements in the field of education signify a transformation of learning processes. In this transformation, the role of digital technological tools surpassing traditional classroom environments is significant (Johnson et al., 2016). These digital technological resources can guide the learning process in a more effective and personalized manner by providing students with personalized learning experiences (Means et al., 2013). In particular, technological and interactive tools are transforming teaching methodologies by allowing students to learn at their own pace (Hew & Brush, 2007; Malik & Shanwal, 2015). These developments increase the importance of interdisciplinary and interactive practices. In this direction, science, technology, engineering, and mathematics (STEM) education is shaped considering these technological advances. This approach aims to create a more holistic learning process by encouraging students to make connections between the fields of science, technology, engineering, and mathematics and to use their skills in these fields in an integrated way (Barakos et al., 2012; Wang et al., 2011). STEM education, characterized as a learning-teaching approach based on interdisciplinary integration and requiring 21st-century skills, focuses on cultivating innovative generations (Bybee, 2010; Honey et al., 2014; Riechert & Post, 2010; United States Department of Education, 2016). As a result, students can develop interdisciplinary thinking skills and effectively guide the learning process through interactive tools offered by technology (Honey et al., 2014; National Research Council (NRC), 2011). This new educational approach is effective in cultivating individuals equipped to meet the needs of the future (Bardak & Polat, 2019; Kanadli, 2019).

While STEM education constitutes one of the leading areas of change in education (Suwarma & Kumano, 2019), it provides students not only with basic knowledge and skills but also vital skills such as analytical thinking, decision-making skills, creativity, and cooperation (Corlu et al., 2014; Dogan & Kahraman, 2021; NRC, 2011; Pekbay, 2023; Sahin et al., 2014). In this context, STEM education offers students the opportunity to develop skills such as problem-solving and critical thinking, reflecting its potential to prepare them for complex and multifaceted issues of the future (Pekbay & Kahraman, 2023; Sanders, 2009; Wang et al., 2011). In addition, STEM education can enable students to cope with the technological challenges they will encounter in their daily lives and make effective contributions in these fields (Honey et al., 2014). Therefore, STEM education has the potential not only to shape learning processes but also to shape the future workforce (McPherson & Anid, 2014).

Countries, in line with the developments in recent years, should make reforms in education systems to be included in global competition and to raise qualified individuals. It implements new education models for education reforms and works to spread these new education models to all segments of society. The most important of these models is the STEM education mentioned above (Bircan et al., 2019). In today's world where technological

developments are advancing without slowing down, STEM education not only trains individuals who are experts in these fields but also supports social development. Therefore, the effective implementation of STEM education and the evaluation of its results have attracted the attention of educational researchers and practitioners. Therefore, this study aims to gain a deeper understanding of current trends, priorities, and developments in the field of STEM education by examining scientific studies conducted using a meta-analysis method through bibliometric analysis and content analysis.

In recent years, the importance of the STEM education approach in educational practices has been examined in many studies. Studies have shown that STEM education increases students' field knowledge success (Acar et al., 2018; Akdag, 2017; Aydin Gunbatar & Tabar, 2019; Judson, 2014; Olivarez, 2012; Tasci & Sahin, 2020; Wade Shepherd, 2016; Wosu, 2013), and interest in STEM fields and learning are positively affected (Antink Meyer & Meyer, 2016; Becker & Park, 2011). Problem-solving skills can be gained by students through STEM activities (Fortus et al., 2005; Meyrick, 2011; Pekbay, 2017; Saleh, 2016; Sahin et al., 2014; Tasci & Sahin, 2020; Wosu, 2013). In addition, studies have shown that STEM education positively affects students' scientific process skills (Gokbayrak & Karisan, 2017), attitudes toward STEM subjects (Azgin & Senler, 2019; Bircan, 2019; Canbazoglu & Tumkaya, 2020; Yilmaz et al., 2017), STEM competencies (Murphy & Mancini Samuelson, 2012), STEM perceptions (Cinar et al., 2016; Guler et al., 2017; Radloff & Guzey, 2016), and engineering thinking (Aydin Gunbatar & Tabar, 2019). At the same time, research focuses on eliminating students' conceptual misconceptions (Antink Meyer & Meyer, 2016), awareness levels (Bakirci & Karisan, 2018; Tezsezen, 2017), conceptual understanding (Breiner et al., 2012; Radloff & Guzey, 2017), perceptions (Nadelson et al., 2013; Pimthong & Williams, 2018), and orientation and intentions (Haciomeroglu, 2018; Li et al., 2019). These studies emphasize that STEM education contributes to various student development and plays an important role in shaping future educational approaches.

Within the scope of this study, as the importance and effects of STEM education are increasing, it is desirable to understand in more detail how research in this field has developed as a whole and which themes stand out. In this context, meta-analysis studies on STEM education within the study provide the opportunity to examine different studies collectively and to evaluate the results of these studies from a general perspective. In the academic context, meta-analysis studies are preferred as a source of data because they can make scientific evidence stronger, reliable, and generally valid by bringing together data from different studies. Meta-analyses systematically combine data from multiple independent studies on a specific topic or research question into a larger and more representative sample, allowing researchers to draw stronger conclusions and make more precise scientific inferences. Meta-analyses also offer the advantage of analyzing heterogeneity and inconsistency across studies, which allows for a deeper understanding of why results may differ (Rosenthal & DiMatteo, 2001). Furthermore, meta-analyses have been used to examine the effects of interventions in various fields. Overall, meta-analysis

studies are frequently used in the academic world to provide strong scientific evidence and enrich the research literature by synthesizing data from multiple studies, analyzing heterogeneity, and drawing more robust conclusions (Nascimento et al., 2018; Rosenthal & DiMatteo, 2001). Therefore, meta-analysis studies are frequently used in the academic world to provide strong scientific evidence and enrich the research literature. Therefore, examining the studies carried out in the field of STEM education using the meta-analysis method will enable us to understand the trends, approaches, and results in this field more deeply. In addition, the bibliometric analysis and content analysis methods used in this article are important in terms of presenting an overview of the literature in the field of STEM education and understanding the scope of studies in this field. The aim of this research is to analyse the most current (2015-2023) literature on STEM education to gain a deeper understanding of current trends, priorities and developments in the field of STEM education. A comprehensive review of studies in the field of STEM education will contribute to a better understanding of trends and emphases in STEM education. These analyses can guide the direction and focus of future research in STEM education and contribute to the development of education policy in this area. In this context, the sub-problems of the research are as follows:

1) How is the distribution of scientific studies conducted using the meta-analysis method in the field of STEM education according to their descriptive characteristics (years, languages of publication, authors, institutions/universities and countries)?

2) How is the distribution of scientific studies conducted using the meta-analysis method in the field of STEM education according to bibliometric features (co-citation network, co-authorship network and common key concepts)?

3) What is the status of the content analysis of scientific article studies conducted using the meta-analysis method in the field of STEM education?

METHOD

Model of Research

In this study, scientific studies carried out with the meta-analysis method in the field of STEM education were examined using bibliometric and content analysis, which are among the systematic compilation methods. A systematic review is a comprehensive examination of the studies conducted in that field to find an answer to a research question or problem, and evaluation and analysis according to the determined criteria (Burns & Grove, 2007; Higgins & Green, 2011). This approach was used to systematically summarize and provide a critical review of the existing scientific literature in the field of STEM education. This study aims to synthesize current knowledge in the field and present key findings to guide future researchers.

Data Collection

The bibliometric analysis of the study was carried out according to the systematic compilation method. First, by accessing the Web of Science (WoS) database, which is frequently used and preferred by scientists (Meho & Yang, 2007), a search was made with "STEM education " and "Meta-analysis " keywords. The limitation of the survey to two key words is due to the examination of meta-analysis studies in the field of STEM education. In this context, it has been seen that there are 38 studies in total, including the relevant key words, since 2015, in the survey conducted on 14.08.2023. Since meta-analysis studies in the field of STEM education began to be conducted in 2015, this was determined as the starting date. Accordingly, 38 scientific studies were included in the bibliometric analysis sections of the study, and the inclusion criteria of scientific studies related to screening are presented in Table 1.

Table 1

Inclusion Criteria

Database	WoS (Web of Science Core Collection)
Index	All of them
Date	14.08.2023
Years	All of them
Publication Type	All of them
Key Concepts	"STEM education" and "Metaanalysis" in the title
Result	38 Publication

Within the scope of the content analysis carried out according to the systematic compilation method, studies that meet the inclusion– exclusion criteria of the study's data. In this research, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guide was used to conduct a systematic review (Liberati et al., 2009). The full text in English, which explores the key concepts of "STEM education and meta-analysis in the subject area of scientific studies in the research, was chosen from among the meta-analysis studies published in peer-reviewed journals. This selection was made from the WoS database. The main selection criteria in the research, such as excluding studies that do not comply with the PRISMA flowchart, excluding academic studies without full text, and exclusion of review studies, theses, books, interviews, and commentary articles, are given in Figure 1.

In the survey conducted on 14.08.2023, it was seen that there were 38 scientific studies including the relevant key words since 2015 without any year limitation. When the related studies were limited to the "article" category, content analysis within the scope of the study was carried out with 18 scientific studies.
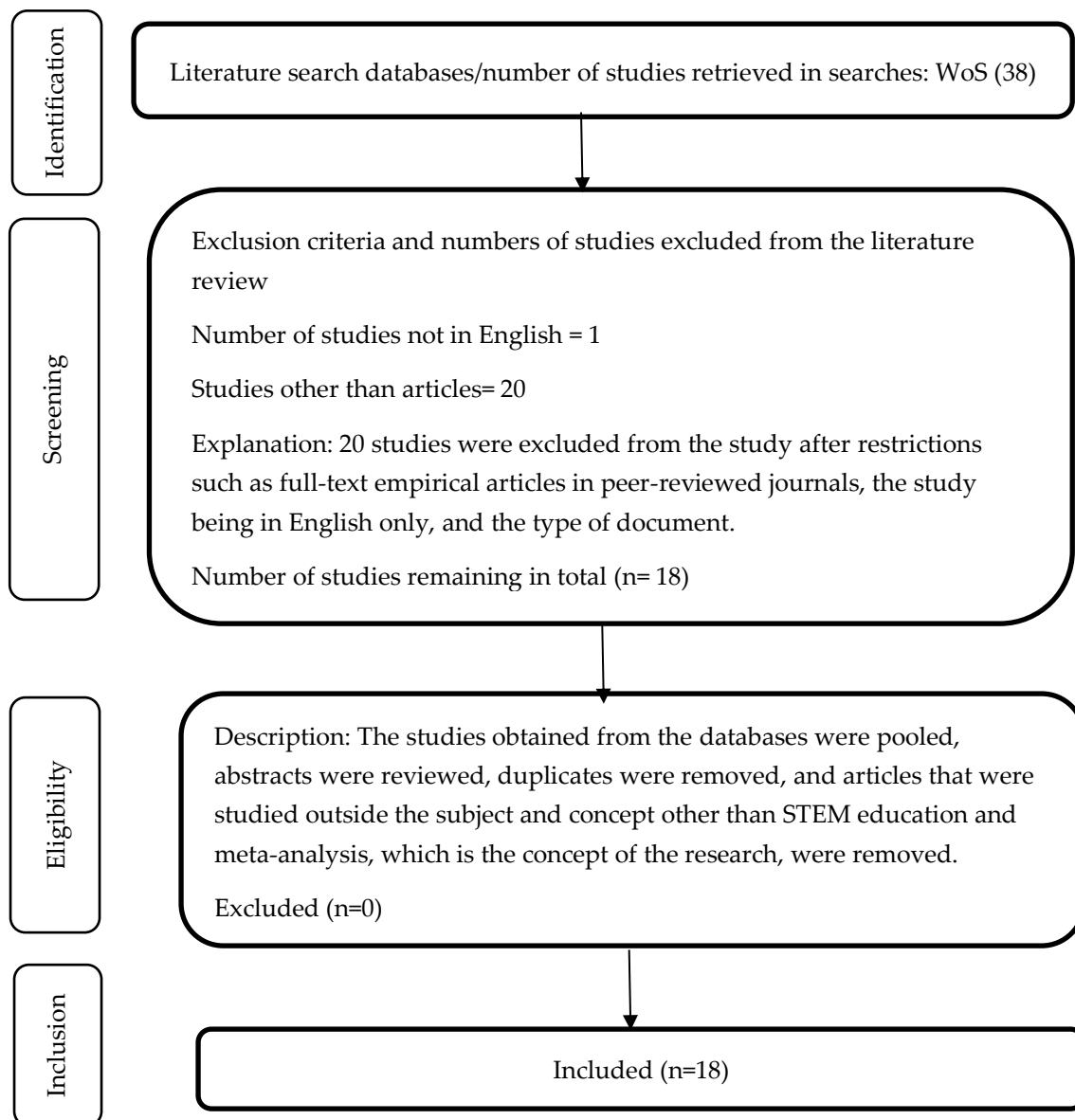
Literature search databases/number of studies retrieved in searches: WoS (38)

Exclusion criteria and numbers of studies excluded from the literature review

Number of studies not in English = 1

Studies other than articles= 20

Explanation: 20 studies were excluded from the study after restrictions such as full-text empirical articles in peer-reviewed journals, the study being in English only, and the type of document.

Number of studies remaining in total (n= 18)

Description: The studies obtained from the databases were pooled, abstracts were reviewed, duplicates were removed, and articles that were studied outside the subject and concept other than STEM education and meta-analysis, which is the concept of the research, were removed.

Excluded (n=0)

Included (n=18)

Figure 1. PRISMA Flowchart

Analysis of the Data

The data were examined using bibliometric and content analyzes. Bibliometric analysis reveals the general characteristics of publications in a particular subject or field using statistical methods. Bibliometric analysis is a statistical evaluation of scientific publications that measures and quantitatively describes their influence over time (Felice & Polimeni, 2020). This analysis method is used to identify features such as the most frequently cited publications, the influence of authors, and the frequency of studies (Pritchard, 1969). Ensuring a solid foundation of bibliometric studies results in the emergence of well-structured works that are original and meaningful (Donthu et al., 2021). Content analysis, another analysis preferred within the scope of the study, examines the contents of the studies in detail and helps us to understand which topics are discussed more frequently,

which concepts stand out, and which learning objectives these studies emphasize (Calik & Sozbilir, 2014). It can provide qualitative insights into the topics and themes in a body of literature (Ellili, 2022). Therefore, both bibliometric and content analysis methods were preferred in this study.

Following the specified criteria, 38 studies accessed from the WoS database were initially subjected to descriptive analysis. Based on the analysis results in the WoS database, these scientific studies were analyzed according to the identified descriptive research problems and explained with visual support. Then, the obtained data were recorded and analyzed on the basis of author, institution/universities in terms of citation counts, co-citation, co-authorship, co-existence, and bibliographic matching analysis types, which are called bibliographic features, using the VOSviewer program. In this framework, the analysis type, analysis unit, and counting method used in the analysis of the data are presented in Table 2.

Table 2

The type of Analysis, Units, and Counting Methods Used in Data Analysis

Analysis Type	Analysis Unit	Counting Method
Co-authorship	Authors	
	Countries	
	Organizations	Full counting
Co-citations	Cited authors	
	Cited references	
Co-occurrence	Keywords	

Then, content analysis of 18 articles published in the Web of Science database, which was carried out using the determined method, was carried out. While conducting content analysis, the studies were examined in the context of author/authors, year, purpose, and findings/results, and the results were tabulated.

Ethical considerations

Because the research has only one author, there is no conflict of interest in the study, and the author has declared that he complies with all ethical rules. In addition, because this study was not conducted on any living thing, it does not require an ethics committee approval certificate.

RESULTS

In this section, the scientific studies that are the subject of the research are examined in terms of bibliometric and content features, answers to the research questions are sought, and the findings are presented below.

The First Subproblem: How is the distribution of scientific studies conducted using the meta-analysis method in the field of STEM education according to their descriptive characteristics (years, languages of publication, authors, institutions/universities and countries)?

The findings obtained from bibliometric analysis based on the descriptive characteristics of the scientific studies included in the research (such as years, publication languages, authors, institutions, journals, and countries) are presented under the following headings:

Distribution of publications by years: The distribution of scientific studies by years is shown in Figure 2.
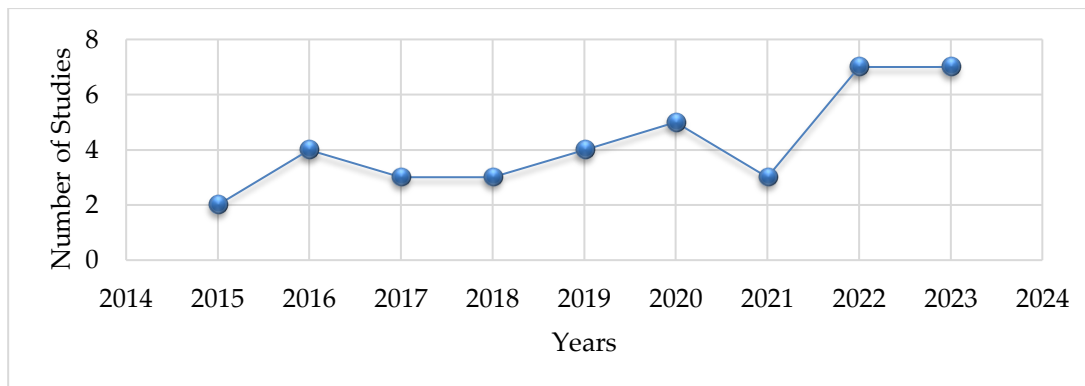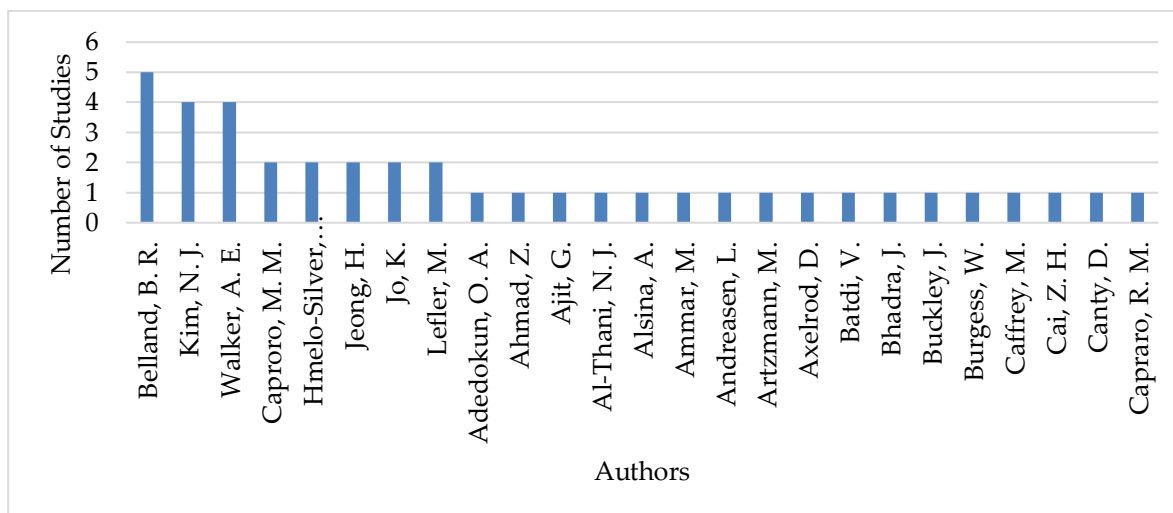

Figure 2. Distribution of Scientific Studies by Year

When Figure 2 is examined, it is seen that the first scientific studies started to be published in 2015 (2 studies) with the method determined in the relevant field, it continued by doubling in the following year, and although there was a decrease in the following year, it generally continued to increase in the following years. In general, the number of studies does not increase at the same rate every year and shows a fluctuating trend. However, when the slope is considered in general, it is seen that the studies start slowly at the beginning and increase in the following years. Considering that as of the date of this analysis, the year in which the study was conducted is still ongoing, it is anticipated that the number of studies in the relevant field will likely increase this year.

Distribution of publications by publication languages: It was determined in the analysis that 37 of the 38 studies conducted using the meta-analysis method in the field of STEM education were published in English and only 1 study was published in Spanish. This finding is important for addressing the language preference of research in STEM education and international science communication This indicates that researchers prefer a more

common language to communicate their studies to a wider audience and to evaluate opportunities for scientific collaboration at the global level.

Distribution according to the number of articles per author: The distribution according to the number of scientific studies per author is shown in Figure 3.

Figure 3. Distribution by Number of Scientific Studies Per Author

Figure 3 shows that 140 authors contributed to the creation of 38 scientific studies on the related subject in the WoS database. This chart shows 25 authors out of the total number. In this context, Belland has conducted the most scientific studies in the relevant field with a total of (5) studies. Afterwards, Kim and Walker enter (4). It is seen that Caproro, Hmelo-Silver, Jeong, Jo, and Lefler (2) each contributed to the field with scientific studies. However, it was observed that all other authors contributed to the field with a scientific study. These findings show that Belland has contributed the most to studies in this field, indicating that this researcher has played a pioneering role in this field and that his work has received wide attention. Other researchers such as Kim, Walker, Caproro, Hmelo-Silver, Jeong, Jo, and Lefler have also made significant contributions. This shows that various subtopics in the field of STEM education are addressed by different experts, and their work adds significant value to the field. The findings also reflect the diversity of research in STEM education and the wide interest in this field. The contributions of different authors with different perspectives contribute to the diversification and deepening of knowledge in this field. This is a positive sign for the development of STEM education.
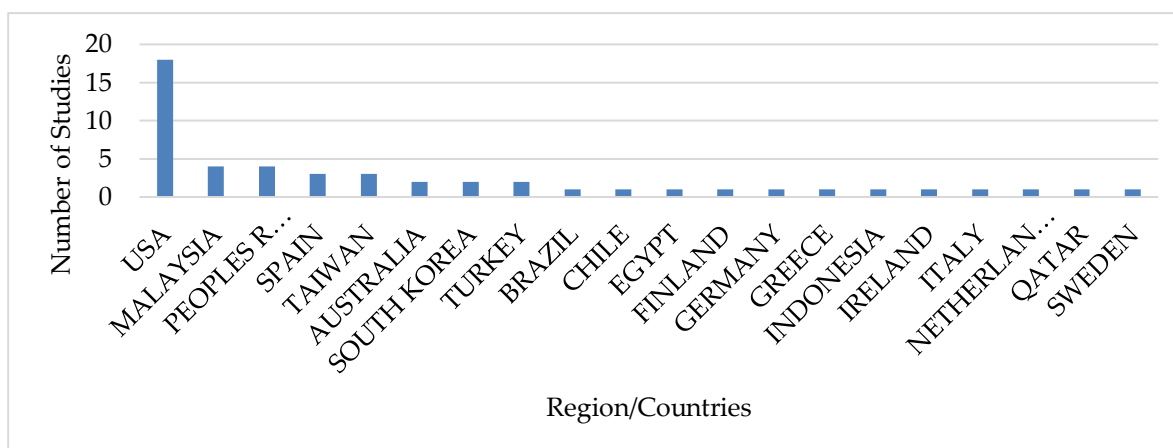
Distribution of publications by institutions/universities: The distribution of scientific study authors by institution/university is shown in Figure 4.
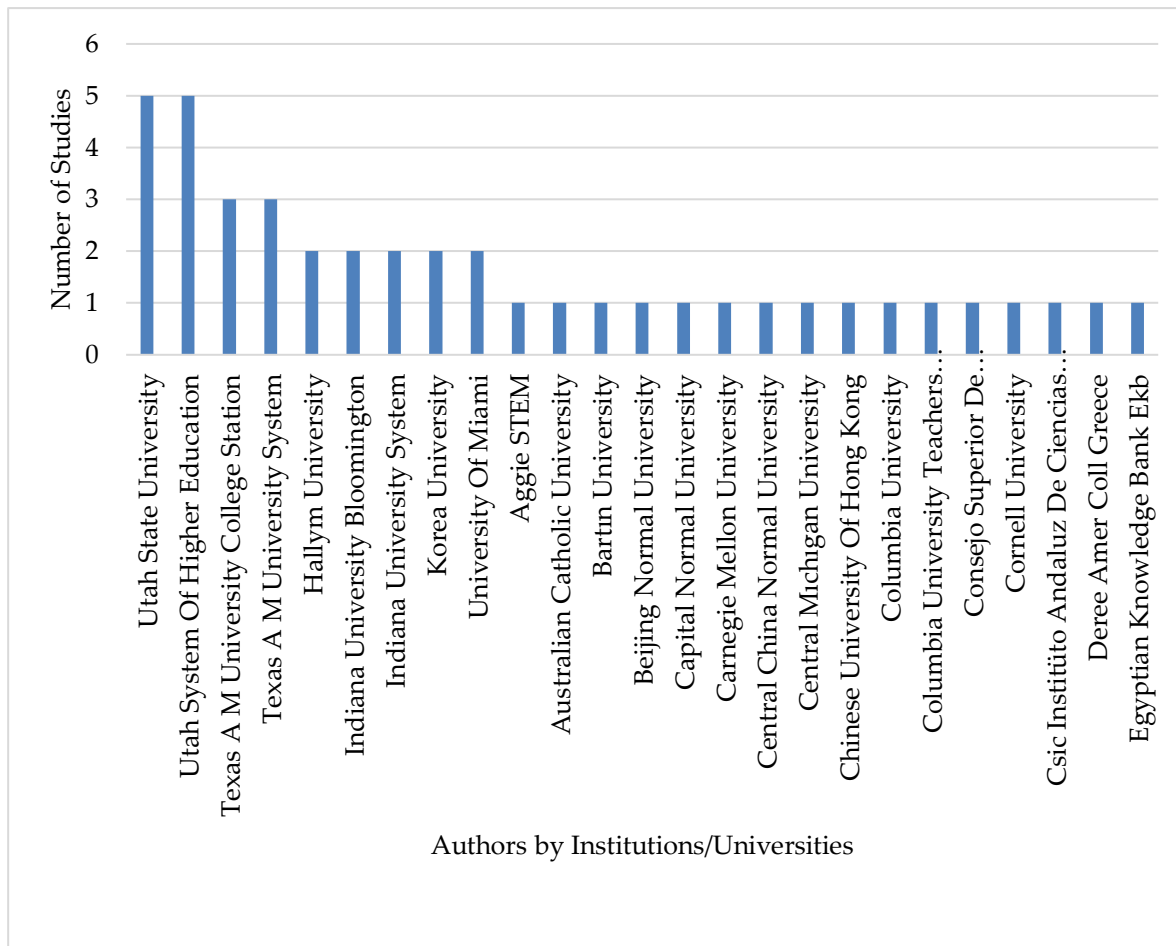
Figure 4. Distribution of Scientific Study Authors by InstitutionsandUniversities

Figure 4 shows the distribution of the authors who contributed to the creation of 38 scientific studies on the related subject in the WoS database, according to the institutions and universities with which they are affiliated Figure 4 shows that Utah State University and the Utah System of Higher Education have the highest number of scientific studies in this field. In addition, three scientific studies were conducted from Texas A&M University College Station and Texas A&M University System; and 2 scientific studies were conducted, each from Hallym University, Indiana University Bloomington, Indiana University System, Korea University, and University of Miami. These findings can be interpretable that Utah State University and the Utah System of Higher Education are the institutions that have contributed the most to scholarly work in this area, although other institutions have also made significant contributions. It has been determined that all other authors have conducted a scientific study at their institutions.

Distribution of publications by country: The distribution of scientific studies by region/country where they are published is shown in Figure 5.

Figure 5. Distribution of Scientific Studies by Region/Countries Where They Are Published

Figure 5 shows the 20 countries in which the publications containing the relevant key concept in the WoS database were generated. Because of the examination of Figure 5, the highest number of scientific studies in this field were published in the USA (18). Malaysia (4) and China (4), respectively; Spain (3) and Taiwan (3); Turkey (2), Australia (2), and South Korea (2) have been observed to contribute to this field with scientific studies, while all other countries have taken part in a field related to scientific study. In addition, the figure shows that there is a sharp decrease in the number of publications from other countries after the United States. According to these data, most of the scientific studies on the key concepts analyzed in the WoS database are conducted in the USA, which is an important leader in this field. Among other countries, Malaysia and China make significant contributions to studies in this field, but there is a significant decrease in the number of publications after the USA. Other countries make a limited contribution in this field.

The Second Subproblem: How is the distribution of scientific studies conducted using the meta-analysis method in the field of STEM education according to bibliometric features (co-citation network, co-authorship network and common key concepts)?

According to the descriptive features of the scientific studies included in the research (co-citation network, co-authorship network and common key words), the findings obtained because of the bibliometric analysis are presented under the following headings. In this context, in the network visualization maps created with the VOSviewer program, the thickness of the lines represents the power of cooperation, the size of the circle indicates the number of articles, and the colours indicate the cluster of collaborations.

Author co-citation network of publications: Figure 6 shows the network visualization map showing the collaborative power of authors who conduct scientific studies.
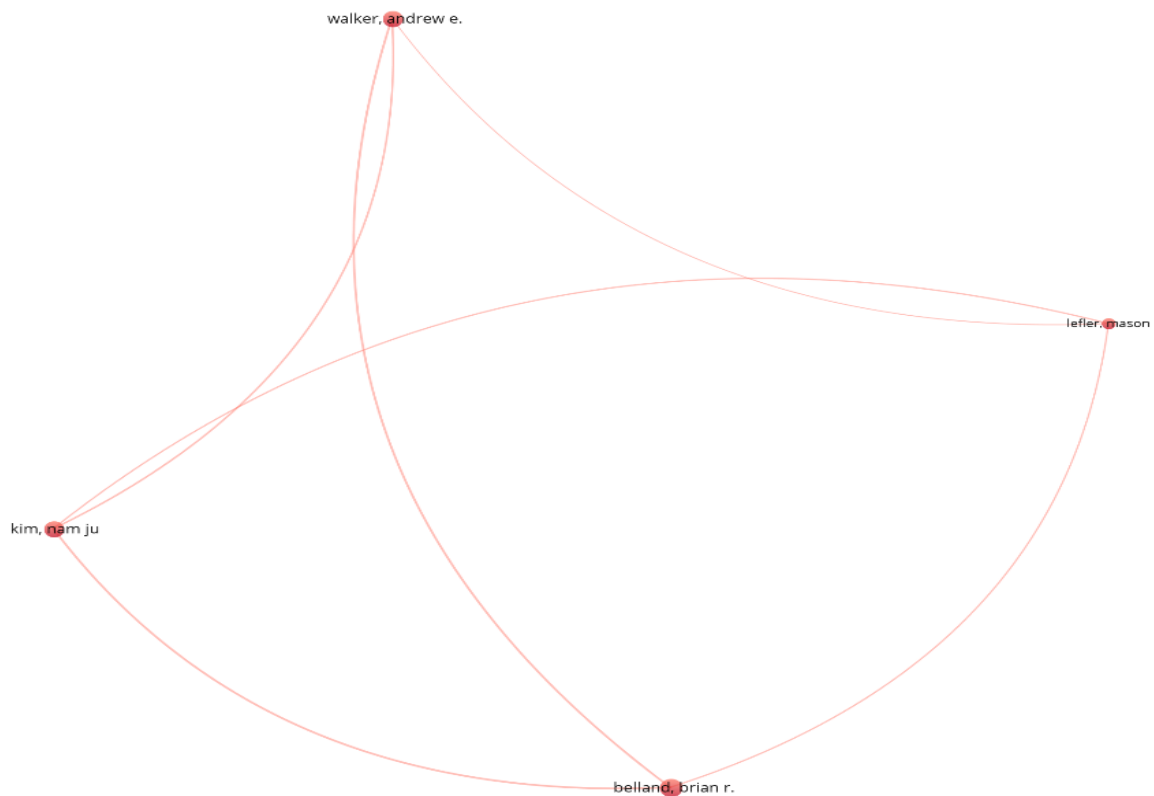
Figure 6. Co-authorship Network Visualization Map for Authors

While creating the network visualization map in Figure 6, a condition was set in the VOSviewer program that required at least two articles per author. This condition was met by 8 of 140 authors. In the network visualization map made later, clusters were created based on author collaborations and are thus seen in red as a single cluster. Because there are only 8 authors in the network visualization map that meet the condition of at least two articles per author, clusters based on author collaborations are shown in a single red colour on the map.

Common citation network of publications according to the institutions/universities with which the authors are affiliated: Figure 7 shows the network visualization map showing the collaboration power of the institutions/universities with which the authors are affiliated.
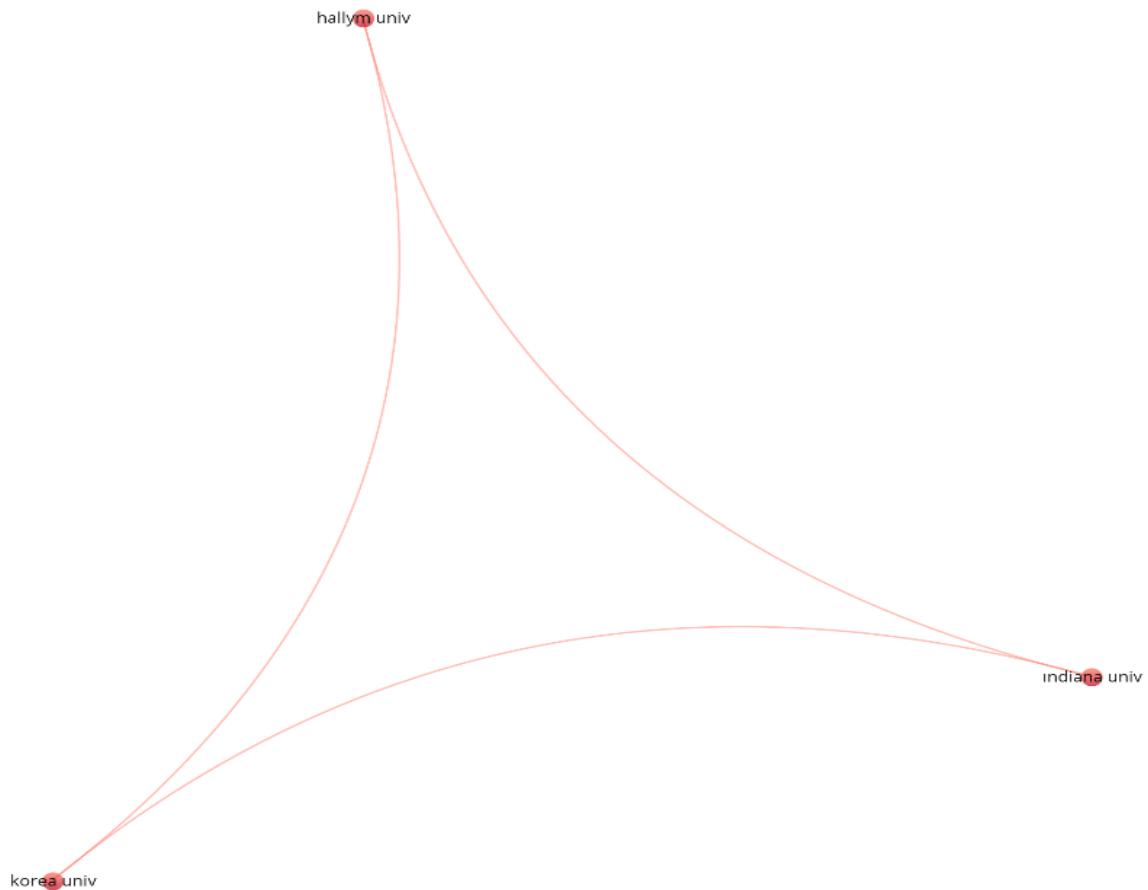
Figure 7. Co-authorship Network Visualization Map by Author Institutions/Universities

When generating the network visualization map in Figure 7, a condition was set in the VOSviewer program that required a minimum of two articles per institution/university. Because of this condition, 6 of 63 institutions or universities fulfilled this condition. Then, in the network visualization map created, 3 different institutions or universities " Hallym" University, Indiana University, and Korea University " seem to be in cooperation. This was expressed under a single cluster according to the cooperative connection status.

Network of co-authorship of publications by region/country: Figure 8 shows the collaboration strength of the region/country where the authors are located.

Figure 8. Co-authorship Network Visualization Map of Publications by Region/Country of Authors

While creating the network visualization map in Figure 8, a condition was set in the VOSviewer program that required at least two articles per region or country. Because of this condition, it has been observed that 8 of 20 regions or countries meet this condition. In the network visualization map created, it is seen that 5 different regions or countries are in cooperation and are divided into two different clusters according to their connection status. The red cluster consists of 3 regions or countries, "Malaysia, South Korea, and the United States", and the green cluster consists of 2 regions or countries, "China and Taiwan". These results show that scientific cooperation between specific regions or countries is prominent and that this cooperation network is divided into two distinct clusters.

Distribution of publications by co-cited authors: Co-citations of cited authors are shown in Figure 9.
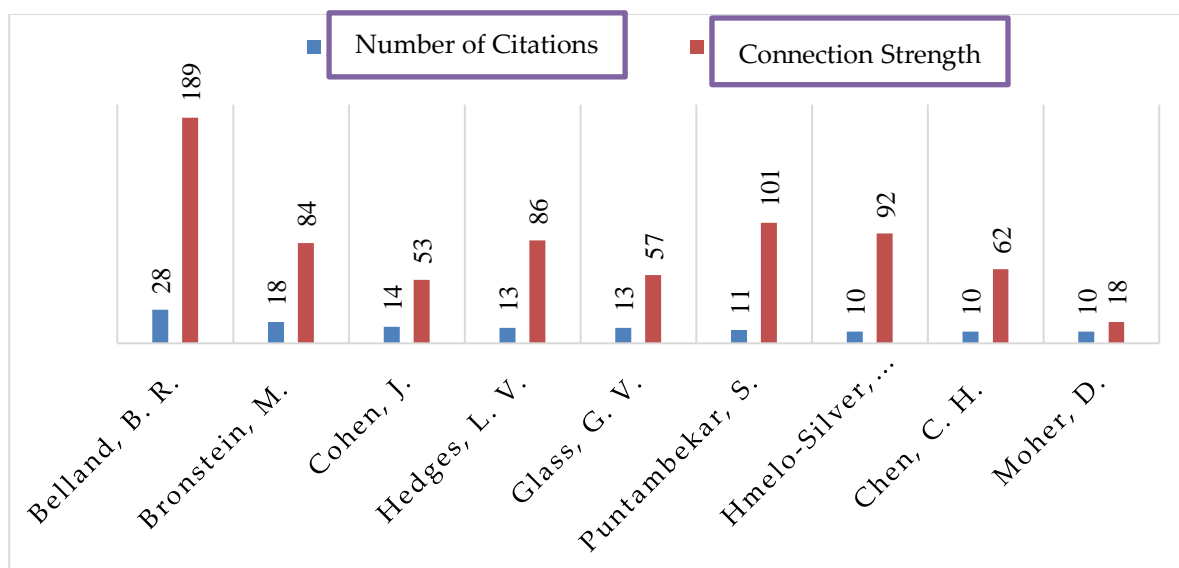

Figure 9. Co-Citation of the Cited Authors

In Figure 9, the minimum number of citations for the co-authors of the publications was determined as 10, and it was observed that 9 out of 2084 authors fulfilled this condition.

Figure 9 shows the total number of citations and link strengths of these authors. Co-citation refers to the frequency of simultaneous citation of two articles by other articles in the case of a bibliographic match (Cunill et al ., 2019). In this context, the visual in the figure shows that the closeness and relationships between the authors are strong. In addition, when the total link strength is taken into account, it is observed that the author named Belland, BR stands out as the most cited author. This image shows that this group of authors collaborate extensively with each other, reflecting the strong closeness and relationships between the authors. Furthermore, based on the total link strength, Belland, BR is the most cited author. These results indicate that this group of authors is effectively engaged in scholarly collaboration and that Belland, BR's work has had a significant impact in various fields.

Distribution of publications by commonly cited sources: The network visualization map of the distribution of publications by commonly cited sources is shown in Figure 10.
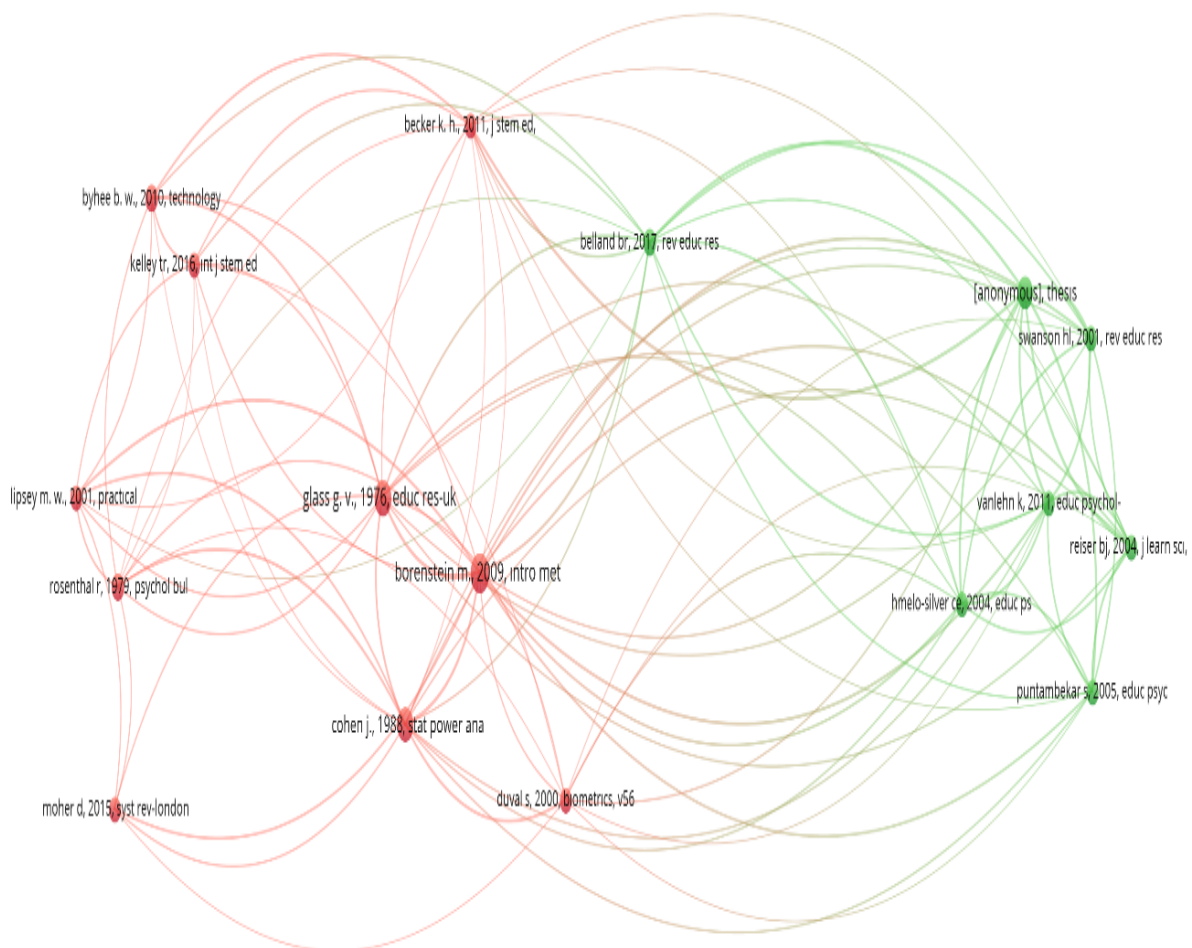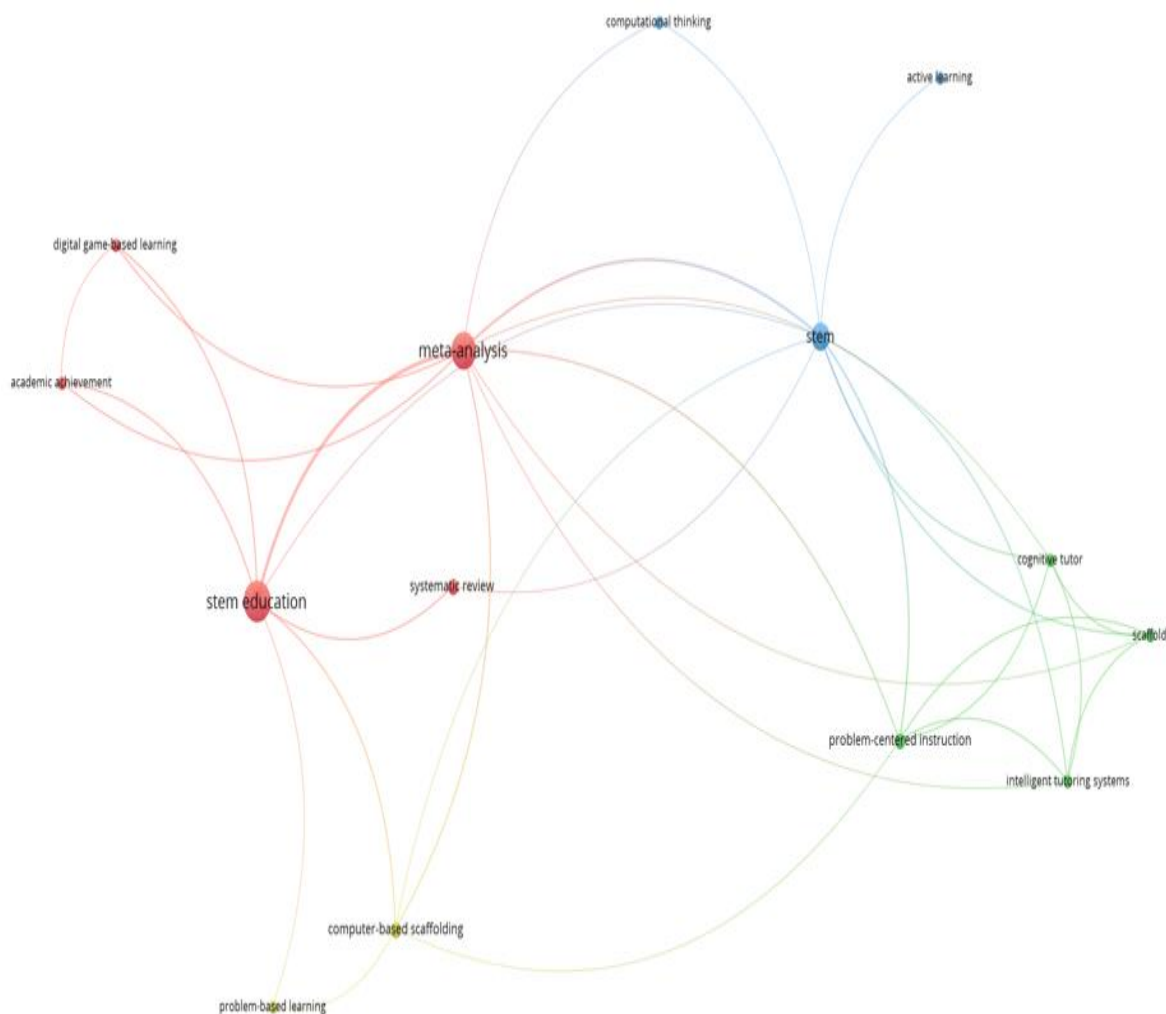

Figure 10. Network Visualization Map of the Distribution of Publications from Commonly Cited Sources

In the network visualization map presented in Figure 10, the 17 commonly cited sources that meet the specified conditions are divided into 2 different clusters, red and green. The network visualization map presented in Figure 10 depicts the distribution of

publications based on their shared references. This map divides 17 sources meeting the specified criteria into two different clusters: red and green. When evaluated in terms of the common references among the cited sources, a minimum citation count of 5 was set for each cited source, and 2691 sources meeting this criterion were identified among the cited references. This finding shows that many sources are frequently cited in scientific studies and that these sources play an important role. Accordingly, the source receiving the highest number of citations from the cited references is a book chapter authored by Borenstein in 2009. This chapter holds the top position in terms of citations (12) and link strength (51) in meta-analysis studies in the field of STEM education. These results show the importance of this book chapter in the field of STEM education and that it is a frequently consulted resource in a wide range of research literature.

Common keywords most used in publications: Figure 11 shows the most used keywords in scientific studies and the links to their use in the network visualization map.

Figure 11. Network Visualization Map of Combined Use of Keywords in Publications

The network visualization map in Figure 11 shows the combination of keywords. While the network visualization map was created with the VOSviewer program, the

minimum number of keywords was determined to be 2, and it was seen that 14 of 118 keywords met this condition. Accordingly, the 14 keywords included in the network visualization map are divided into 4 different clusters which are red, blue, yellow, and green according to the frequency of use together. Accordingly, apart from "STEM", "STEM education", "meta-analysis", " computer-based" learning ", " digital game-based learning ", " academic achievement ", " active learning " and "problem-centred It is seen that there are key concepts that evoke technology such as "instruction ". This situation can be interpretable that STEM education and technology-enhanced learning are important focal points in the studies and that these terms are frequently discussed together.

The Third Subproblem: What is the status of the content analysis of scientific article studies conducted using the meta-analysis method in the field of STEM education?

In this section, content analysis of 18 articles published in the WoS database, which was carried out using the method determined in the relevant field, was carried out (APPENDIX). The findings obtained from the content analysis are presented in Table 3.

Table 3 shows that the studies are generally aimed at determining the effect of a method in STEM education on the performance of students in that field. While 4 of the conducted studies focus on a particular field, it is seen that the studies generally approach STEM education holistically and try to reveal the variables that are considered, considering that they may directly or indirectly affect the performance in this field.

Table 3

Content Analysis Findings of Scientific Article Studies Conducted with Meta-Analysis in STEM Education

Row	Author(s) / Years	Purpose	Results
1	Santhosh and collages (2023)	To investigate the impact of an informal project-based learning model on students' learning outcomes compared with a traditional classroom environment.	The informal project-based learning method had moderately significant effects on students' learning outcomes compared with the traditional learning method. The overall effectiveness of the informal project-based learning method was influenced by the teaching model, the assessment method, student group size, and course duration.
2	Arztmann, Hornstra, Jeuring, and Kester (2023)	To examine the effects of game interventions on different student groups in STEM subjects.	Using a game-based learning approach in STEM education has a moderately positive effect on cognition, motivation, and behaviour. It was concluded that primary school students achieved higher learning outcomes and experienced game interventions as more motivating than secondary school students and that gender did not have any moderating effect.

3	Zhang, Zhou and Zhang (2023)	To examine the magnitude of the relationships between STEM interventions/ programs and teachers' perceptions of STEM.	All intervention types were found to be effective in improving teachers' STEM knowledge, STEM teaching skills, and students' perceptions of STEM learning. The strongest impact of curriculum-based interventions and interventions focusing on professional development was observed in the development of teachers' STEM knowledge. In-service teachers tended to benefit more from the interventions in terms of both STEM knowledge and STEM teaching skill perceptions.
4	Yucelyigit and Toker (2021)	To examine the effect of STEM studies on learning and development in early childhood education.	The STEM approach was found to have positive effects on preschool children's learning and development. It was concluded that the implementation of STEM activities in the preschool period improves children's skills in STEM fields. In addition, it was concluded that the implementation of STEM activities in the preschool period improves children's skills in mathematics, science, and technology. This study provides an encouraging recommendation for preschool teachers to include STEM practices in their classrooms.
5	Williams and Young (2021)	To characterize the application of reliability generalization meta-analytic studies in empirical research on mathematics education.	Because of the analyses carried out in the article, it was seen that the reliability generalization meta-analytic studies on mathematics education did not mention the reliability of the articles examined among the studies or cited previously reported reliability.
6	Siregar, Rosli, Maat, and Capraro (2020)	To analyze the results of STEM program studies that affect students' mathematics achievements.	It was concluded that STEM impacts students' mathematics achievements. The effect of the STEM program on students' mathematics achievements did not depend on the variables of education level, source of publication, or length of intervention.
7	Parker, Van Zanden, Marsh, Owen, Duineveld and Noetel (2020)	To assess the intersection of gender, social class, and cultural context by exploring gender differences in STEM-related expectations of success.	Gender differences were generally found to have small effect sizes. Using the concept of intersectionality, we find that heterogeneity in gender effect sizes is large and that gender differences are primarily moderated by socioeconomic status, ethnic diversity, and, to some extent, national gender equality.
8	Fidai, Capraro, and Capraro (2020)	Examining the effect of computer-assisted instruction on students' computational thinking skills.	The use of computer-assisted instruction was found to have a positive effect on students' computational thinking skills.

9	Kim and collages (2020)	To determine the effect of group size, the type of computer-aided scaffolding intervention used in groups or individually, and the effect of computer-aided scaffolding.	It shows that computer-aided scaffolding leads to statistically significant cognitive learning effects when students solve problems individually and when working in pairs, triads, and small groups. The moderator analyses also revealed that the effect sizes for groups were higher when students worked in pairs when metacognitive scaffolding was present in group activities, and when there was scaffolding but no collaboration support.
10	Jeong, Hmelo Silver, and Jo (2019)	Examining the effect of computer-supported collaborative learning in STEM education.	Computer-supported collaborative learning in STEM education has a medium-sized effect. This shows that the effects of technology and pedagogy vary depending on the forms of collaboration, students' educational levels, and learning domains.
11	Chase et al., (2019)	Examining how teachers shape students' cognitive engagement and transfer.	Teachers should provide clear and precise instructions, encourage students to share their ideas, and respect students' different perspectives. These results provide insight into how teachers can more effectively guide students to increase their cognitive engagement and transfer.
12	Batdi, Talan, and Semerci (2019)	To examine STEM education from a meta-analytic and meta-thematic perspective and to determine its impact on academic achievement and different variables.	STEM had a moderately significant and positive effect on academic achievement. STEM also had a positive effect on the development of different skills.
13	Lee and collages (2018)	To investigate the success of a course in general chemistry at Cornell University.	This shows that the course for general chemistry at Cornell University led to significant improvements in the final course grades for priority and non-priority students. It has also been observed to lead to progressive improvement and retention in subsequent chemistry courses. These results may help in discussing strategies for developing similar courses in STEM education. However, it is also noted in the research that the results of this study may require a more detailed analysis of the demographic characteristics of the priority students.
14	Belland and collages (2017)	To synthesize the results of 144 experimental studies on the effects of computer-based scaffolding designed to assist STEM students.	Computer-based scaffolding has consistently shown a positive effect on cognitive outcomes across a range of use contexts, scaffolding characteristics, and evaluation levels.

15	Belland, Walker, and Kim (2017)	Examining the effect of using computer-aided scaffolding in STEM education on students' cognitive outcomes.	This shows that the use of computer-aided scaffolding increases students' cognitive outcomes in STEM education. The study found that the use of computer-aided scaffolding was effective in improving students' problem-solving, argumentation, and evaluation skills. Moreover, the effect of scaffolding on students' cognitive outcomes differed across the student population and STEM disciplines.
16	Kim, Belland, and Walker (2017)	Investigating the effectiveness of computer-based scaffolding in the context of problem-based learning for STEM education through a Bayesian meta-analysis.	Computer-based scaffolding significantly affected cognitive outcomes in the context of problem-based learning in STEM education. It was also found that the effects of computer-based scaffolding ranged from small to medium depending on the characteristics and context of the use of computer-aided scaffolding.
17	Belland, Walker, Olsen, and Leary (2015)	To determine the effect of computer-based scaffolding features and study and test score quality on cognitive outcomes in STEM education at the secondary school, university, graduate, and adult levels.	The computer-aided scaffolding model positively affected learning; studies with zero threats for internal validity had lower effect sizes than studies with two threats; studies with one threat for external validity had larger effect sizes than studies with zero threats; and studies with no fading had higher effect sizes than studies with constant fading.
18	Adedokun and collages (2015)	To conduct a meta-analytic evaluation of the impact of a virtual field trip on students' perceptions of scientists.	In addition to the statistically significant effect of each publication, zipTrips had a statistically significant summary (combined) effect on participants' perceptions of scientists.

DISCUSSION AND CONCLUSION

The aim of this research is to examine scientific studies conducted using the meta-analysis method in the field of STEM education according to the specified analysis characteristics. In this context, when we analyze the distribution of scientific studies conducted using the meta-analysis method in the field of STEM education in terms of their descriptive characteristics, we observe a general increasing trend in the number of publications starting in 2015. As of the date of our analysis, this study reveals 7 publications in the literature for the years 2022 and 2023. However, considering that 2023 is not yet complete, it is important to emphasize the possibility of an increase in the number of publications within this year. Similarly, in the studies conducted in the literature, we also observe a rapid increase in the number of studies related to STEM education, highlighting the growing importance of research in this field (Cavas et al., 2020; Sungur Gul et al., 2022).

Furthermore, when analyzing the distribution of scientific studies' authors based on their affiliated institutions or universities, it is observed that both Utah State University and

the Utah System of Higher Education stand out with 5 scientific studies each. However, it is noteworthy that the publications affiliated with the relevant university in the WoS database are often produced by different authors. For example, it is evident that Brian R. Belland's affiliation with Utah State University positions him as one of the most prolific authors in this field. On the other hand, it's noticed that universities like Yonsei University and the University of Miami, where Nam Ju Kim is affiliated, do not rank at the top in terms of productivity. This situation highlights that while authors may stand out individually in terms of productivity, the representation capability of institutions can present a different picture. Thus, it can be assessed that not only prolific authors like Brian R. Belland and Nam Ju Kim as well as other authors play a significant role in representing institutions.

Similarly, when analyzing the distribution of studies based on countries/regions, the United States stands out with 18 scientific studies in this field. This analysis can be considered as an extension of author and university analyses and reflects the natural outcome of previous analyzes. The most productive authors and institutions, when viewed cumulatively, distinctly highlight their respective countries/regions.

In summary, all these analyses shed light on various aspects of studies conducted in the field of STEM education. The prominence of the English language aligns with its status as the universally accepted language of science and fits well with the structure of databases. Likewise, productive authors such as Brian R. Belland and Nam Ju Kim enhance their impact on the field's literature, along with the representation capabilities of their institutions. The distribution of publications across databases and country/region analyses demonstrate the geographic spread of studies and the influence of major publishers, underscoring the comprehensiveness and expanded perspective these analyses offer. Collectively, these results provide a foundation to comprehend different dimensions of scientific research and meta-analysis studies in the STEM education field, contributing to predicting future trends.

When examining the scientific publications in terms of bibliometric characteristics in the study, it is observed that the most productive authors are interconnected and their affiliated institutions/universities collaborate as well. This situation reflects the establishment of a collaboration network at the country/region level. The network visualization map created on a country/region basis particularly shows the United States at the centre of the map, forming strong connections with other countries. This highlights the fact that these leading countries actively collaborate with authors from various countries in terms of publication count and collaboration.

Regarding the total citations and link strength of scientific publications, it is evident that a methodological book chapter stands out in connection with meta-analysis. These publications noticeably elaborate on the meta-analysis method, which is as novel as STEM education itself. Hence, the obtained results are not abnormal. Therefore, the reason for only one of Belland's works receiving the most citations is likely due to the relatively recent

emergence of these works. With the recent citation counts and link strengths of these authors, they are predicted to stand out prominently in this field.

In the analysis, another significant finding is that apart from "STEM", "STEM education" and "meta-analysis," keywords that are prominently highlighted in scientific studies include technology-associated terms such as "computer-based learning," "digital game-based learning," "academic achievement," "active learning," and "problem-centred instruction." This situation allows us to evaluate the trends and focal points of research in the field of STEM education from a broader perspective. The prominence of these keywords aligns with the increasing emphasis on technology integration and the role of digital tools in education within STEM education research. Approaches such as computer-based learning and digital game-based learning aim to provide students with interactive and participatory learning experiences, thereby making learning processes more effective and engaging (Donmez Usta & Ultay, 2022; Hacioglu & Donmez Usta, 2020; Saricam, 2019). These technology-enhanced approaches serve as essential tools to capture students' attention, motivate them, and make learning more meaningful (Donmez Usta & Turan Guntepe, 2019).

Academic achievement-focused studies, on the other hand, examine how STEM education impacts students' knowledge and skill acquisition (Acar et al., 2018; Akdag, 2017; Aydin Gunbatar & Tabar, 2019; Judson, 2014; Olivarez, 2012; Tasci & Sahin, 2020; Wade Shepherd, 2016; Wosu, 2013). In particular, the development of competencies related to STEM fields holds significant importance for students to better respond to future career goals and the needs of the job market (McPherson & Anid, 2014). Active learning and problem-centred instruction represent approaches where students can direct their own learning processes and generate solutions to real-world problems (Fortus et al., 2005; Meyrick, 2011; Saleh, 2016; Sahin et al., 2014; Tasci & Sahin, 2020; Wosu, 2013). These learning methods help students enhance 21st-century skills such as analytical thinking, collaboration, creativity, and critical thinking while offering the potential to make learning more meaningful and enduring (Corlu et al., 2014; Dogan & Kahraman, 2021; NRC, 2011; Sahin et al., 2014; Sanders, 2009; Wang et al., 2011). The prominence of these keywords signifies that STEM education is a holistic approach that not only focuses on subject knowledge but also aims to equip students with the ability to effectively use technology and integrate various skills. These concepts reflect the prominent themes in STEM education research, guiding the shaping of future educational practices and contributing to student development.

Because of the content analysis of the scientific article studies on the meta-analysis method in the field of STEM education, it was seen that these studies generally focused on determining the effect of a method in STEM education on student performance. Wahono and collages (2020) emphasized that studies related to meta-analysis methods in the field of STEM education generally focus on determining the effect of a method on student performance in STEM education. In their meta-analysis study on effective strategies for

integrated STEM education, Mustafa and collages (2016) emphasized that integrated STEM education supports instructional strategies that encourage students to invent and innovate through hands-on activities and project-based learning. The findings of this meta-analysis can be interpretable that integrative approaches in STEM education have positive effects on students' learning. Cakici and collages (2021) specifically focused on the impact of STEM education on students' academic achievement in science courses. Furthermore, Tenti (2021) conducted a meta-analysis to examine the impact of integrating STEM education into various learning models on students' physics learning outcomes. This provides evidence that studies using meta-analysis in the field of STEM education generally focus on determining the impact of STEM education on student performance.

The majority of these studies have approached STEM education from a holistic perspective and discussed the variables that may directly or indirectly affect student performance. It has been noticed that Belland and collages have come to the fore in studies on scaffolding in particular. The results that computer-assisted instruction, project-based instruction, and educational games have positive effects on STEM education are supported by the findings that the STEM education approach contributes positively to development and learning in early childhood. These results also coincide with the key concepts of the study that emerged from the bibliometric analysis. A meta-analysis by Mustafa and collages (2016) on effective strategies for integrated STEM education highlighted that project-based learning, often integrated with STEM, promotes teaching strategies that encourage students to invent and innovate. This hands-on approach enables students to engage in real-world problem-solving and creative design, enhancing learning activities and leading to meaningful learning (Lou et al., 2014). Furthermore, STEM enactments, particularly those that integrate project-based learning, have been found to be effective student learning outcomes (Wahono et al., 2020). The study recommends a combination of learning approaches, orientations, and instruction duration to maximize the effectiveness of STEM education. Moreover, integrating STEM education with creative education and project-based learning has shown positive effects on students' integrated STEM thinking and imaginative ability (Tsai et al., 2017). This student-centred learning model enhances the learning and integration of STEM knowledge. Overall, these findings support the claim that computer-assisted instruction, project-based instruction, and educational games have positive effects on STEM education. These approaches provide students with hands-on, real-world learning experiences that promote problem-solving, innovation, and the integration of STEM knowledge. By engaging students in active learning, these teaching methods positively contribute to their development and learning in early childhood and beyond.

In addition, the results of the moderator analysis of the meta-analysis studies show that the effectiveness of the project-based learning method is affected by factors such as the teaching model, assessment method, student group size, and course duration, that the educational game approach is more effective in younger age groups, and that gender has a

significant effect among different age groups. points to important results that do not make a difference. Various factors influenced the results of the moderator analysis of the meta-analysis studies support the claim that the effectiveness of the project-based learning method. Kokotsaki and collages (2016) explained that project-based learning involves students constructing knowledge by solving real problems, asking questions, conducting investigations, and reporting findings. This study also highlights the importance of collaboration and the need for a shared goal in project-based learning. Mustafa and collages (2016) further emphasized that project-based learning is a dominant strategy in STEM education implementation and improves students' skills and competitiveness in a knowledge-based society. This study can be interpretable that educators should explore how project-based learning can be effectively implemented in their teaching. Regarding the educational game approach, Malik and collages (2017) compared game-based oral health education with conventional oral health education. The results showed that the implementation of a crossword game-based oral health education program significantly increased children's oral health-related knowledge and improved their oral hygiene status. This can be interpretable that educational games can be an effective aid in teaching and preventing oral diseases in children. Furthermore, the literature can be interpretable that the effectiveness of these approaches may vary depending on factors such as age and gender. Wirahayu and collages (2022) found that the application of video-assisted project-based learning was effective in improving students' mathematical creative thinking skills. The study also highlighted the effectiveness of the hybrid learning model in providing knowledge and developing life skills. Additionally, Vega and collages (2022) conducted a rapid review of the use of video games to improve the sexual health of young people. The findings indicated that while there were some promising outcomes, the results across studies were mixed, can be interpretable that the effectiveness of game-based interventions may vary. In summary, the literature supports the claim that the effectiveness of project-based learning and educational games in STEM education is influenced by various factors. These factors include the teaching model, assessment method, student group size, course duration, age group, and gender. Educators should consider these factors when implementing these approaches to maximize their effectiveness.

LIMITATIONS AND RECOMMENDATIONS

While this research provides significant contributions to the literature, there are certain limitations that need to be considered in future studies. This study focused on 38 scientific publications in bibliometric analysis and 18 in content analysis. Furthermore, the study only considered scientific works written in English and available in the WoS database, limited to the concepts of "STEM education and meta-analysis." Therefore, it might not fully encompass the spectrum of STEM education practices. Therefore, there is a need for studies that provide a broader perspective and encompass various concepts. Taking these limitations into account will help future research approach the topic more comprehensively and with a broader perspective.

Considering the limitations of this study, suggestions for future research can be offered. First, increasing the number of studies used in bibliometric analysis and considering different databases can help cover a wider range of literature. Examining more studies while conducting content analysis can help us better understand the diversity and depth of STEM education practices. In addition, examining studies published in different languages beyond the English language, where this study is limited, may strengthen the generalizations of the study as it will include different cultural and geographical perspectives. In this context, it may be advisable to perform similar analyses using a wider range of languages, including publications in other languages. However, conducting studies that examine STEM education practices in more detail and analyze the effects of different learning methods on student achievement in more detail may help future research reach more specific results. Finally, conducting research that goes beyond the studies in this field and examines the impact of STEM education on skills such as general learning experience and critical thinking, as well as student performance, can provide a more holistic understanding.

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APPENDIX

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