A CONTENT ANALYSIS RESEARCH ON STEM ACTIVITY IN COLLEGES

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Abstract

People must be qualified to adapt to developments resulting from the fast evolution of information and technology. This would be accomplished by incorporating technology into instruction. To survive in the world of science and technology, the disciplines that will continue to play a significant role in the future are Science, Technology, Engineering, and Mathematics (STEM). In this respect, several studies have been carried out on enhancing STEM education in colleges. This research aims to evaluate these studies and the trends used to define the scientific content criteria. The citation analysis method investigates STEM-related papers indexed in scholarly publications. A total number of 202 studies published between 2017 and 2022 were examined. According to the study's results, the number of citations and research articles increased remarkably in 2021. This result enables researchers to describe the characteristics of the contents of scientific journals.

Keywords: Bibliometric; Content analysis; STEM; STEM activity

1. INTRODUCTION

Bibliometric is a quantitative analysis method that utilizes mathematical and statistical methods to assess books, journals, and other publications, particularly those with scientific content. Although most social research methods focus on monitoring stimuli and reactions, defining observable behaviors, identifying individual characteristics, measuring social circumstances, and testing hypotheses pertaining to different topics, a few techniques focus on analyzing the relationships between stimuli and responses. One of the important techniques is content analysis.

Citation analysis is one of the important and oldest fields of bibliometric research to assess peer-reviewed literature and summarize publishing trends inside and beyond professional disciplines. This method extends beyond the instantly observable physical vehicles of communication and focuses on their symbolic features to trace the causes, correlations, or results of communications, thus making the (unobserved) context of data analyzable. An essential part of any content analysis methodology is the justification of the inferential step that it entails (Krippendorff, 1989).

The citation analysis method has been employed in various subjects including social sciences (Filiz & Benzet, 2018; Hermann & Bossle, 2020; Jarrín, Pouladi, & Madigan, 2019; Uzunboylu & Beheshti, 2017), medicine (Reid et al., 2019; Webster, Rice, Sud, 2020; Safi, Thiessen, & Schmailzl, 2018), psychology (Cox

& Ward, 2019; Cole et al., 2021; Miller et al., 2019), business (Ritala et al., 2018), economics (Ahmad et al.,2020; Stieger & Jekel, 2019; Chouliaraki & Zaborowski, 2017), etc.

Citation analysis is not only a practical method to specify documents in a given journal with a major number of citations but also shows the effect of research papers on any field (Aylward et al., 2008). This method could be used to examine the research assistance of professional journals, organizations, and individuals (Brown & Gardner, 1985). It enables researchers to investigate how frequently other scientists have cited a study or how effective it is.

According to previous studies conducted in the last five years (2017-2022) in the area of science and engineering education, STEM education was the most popular subject for implementation, particularly at the high school level. As a result, STEM education has emerged as an educational technology field. STEM is a teaching approach initiated by the National Science Foundation, focusing on one or more of the four disciplines of Science, Technology, Engineering, and Math.

To determine how STEM applications affect learning, several research has been conducted. For instance, Fan and Yu (2017) assessed the effectiveness of using a STEM application that integrates engineering design methods in Taiwanese high school technology education. They aimed to observe the performance of students studying a STEM engineering module and compare it with those who were studying the technology education module. The results demonstrated that participants in the STEM engineering module performed significantly better in the areas of conceptual understanding, higher-order thinking skills, and design project activity than participants in the technology education module.

Mayorova, Grishko, and Leonov (2018) studied how to motivate high school students and increase their interest in STEM education applications using modern educational tools. They used tools in experimental courses in mathematics, information technologies, and physics to increase the quality of training activities.

Song et al. (2020) run a STEM workshop organized by the Society of Women Engineers (SWE) student chapter to increase STEM activities for female freshman and sophomore high school students. The outcome showed that students reflected positively about the workshops and desired to participate in more STEM-related activities.

Long, Yen, and Van Hanh (2020) applied micro-learning activities (experiencing, sharing and processing, generalizing, and applying) and asked students to complete a series of experiential tasks in the engineering design process in K-12 STEM education.

Another study, conducted by Arockiasamy et al. (2021), focused on developing a student-centered methodology for integrating NASA-STEM content into existing middle and high school curricula to improve underserved students' knowledge and motivation to pursue STEM fields.

McCue et al. (2022) discussed how to develop a STEM outreach program in robotics for high school students. They provided students with hands-on robotic activities and instructional materials such as videos and written curricular content to promote their interest and learning.

The publication reports between 2017 and 2022 periodically identify and discuss the trends in developing STEM education applications within engineering design practices at the high school level. Although a ping review was carried out, no particular studies were found on the trends in publications concerned with STEM education at the high school level in that specific period. Therefore, this research aimed to determine the trends in publications taken from the Scopus database concerned with STEM education concepts during the period between 2017 and 2022.

2. METHODOLOGY

This study applied the quantitative content analysis technique to the Scopus database to generate results from articles published between 2017 and 2022. This study was conducted using the keywords "STEM education in high school education."

The content analysis criteria of this research led by recent studies conducted by Cumhur et al. (2021), Çevik (2017), Yıldırım (2021), Uzunboylu and Beheshti (2017). The criteria comprise the type of documents published (book, conference paper, journal paper, review paper), publication country, year in which the research was applied, authors, subject area, sample group, and research method. In order Tohese goals, the following research questions were determined:

1. What are the subject areas of the studies?
2. What is the number of publications according to the document types?

3. What is the number of publications according to the year?
4. What is the number of publications according to the authors?
5. What is the number of publications according to the country?
6. What is the analysis result of the most frequently cited articles?

3. FINDINGS

3.1 Distribution of Articles According to Subject Areas

Various studies related to STEM education have been undertaken in the referred academic journals. The fields include engineering, social sciences, computer science, physics and astronomy, decision sciences, earth and planetary sciences, chemistry, biochemistry, genetics, molecular biology, energy, mathematics, and many others (see Figure 1).

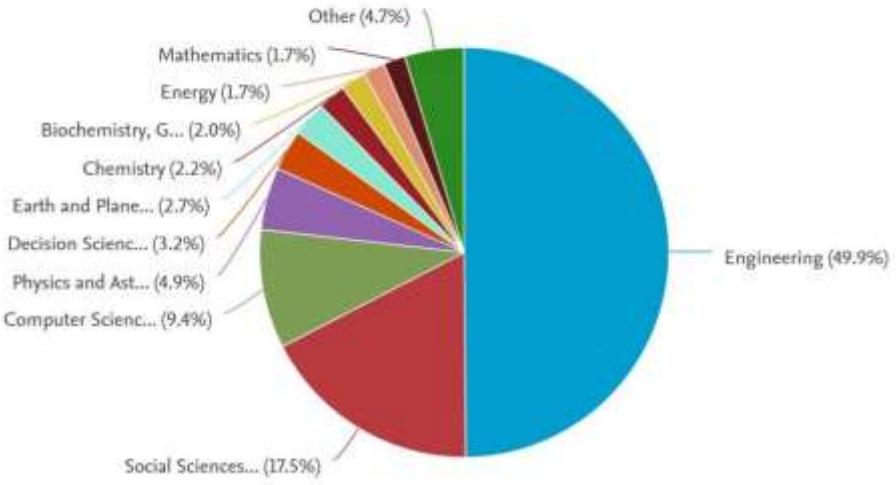

Fig. 1: Subject area distribution of publications

As illustrated in Figure 1, the topic has been used in studies in a variety of subject areas between 2017 and 2022. With a rate of 49.9%, engineering was the most popular subject for implementation. As a result, STEM education has emerged as an educational technology field. Moreover, all the studies examined were created using document-based citation analysis instead of journal content analysis, as had previously been the norm. Citation analysis was first used in the 1950s, thanks to Garfield (1955), who suggested the technique of citation indexing. The Science Citation Index-Expanded (SCIE), Arts, Humanities, and Social Sciences Citation Index (SSCI), and the Institute for Scientific Information (now Thomson Reuters) comprise these citations, so the methodological analysis began with research trends and the effectiveness of scholarly works.

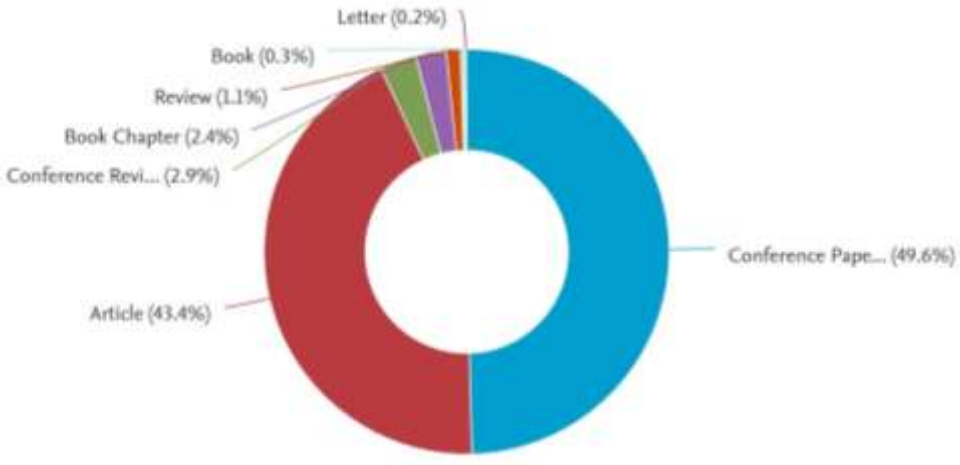

Fig. 2**:** Types of published documents

3.2 Document Types

As shown in Figure 2, the most common papers related to STEM education published in various sources between 2017 and 2022 were conference papers (n = 139, 68.8%), articles (n = 59, 29.2%), book chapters (n = 2, 1.0%), conference reviews (n = 1, 0.5%), and review papers (n = 1, 0.5%).

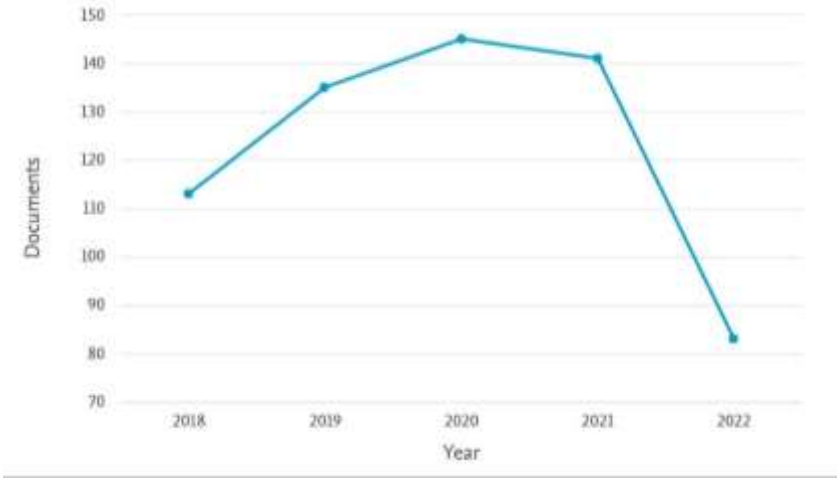

Fig. 3**:** Published articles by year

3.3 Publication Year

From 2017 to 2022, the number of papers on the subject of STEM education decreased yearly (see Figure 3), from 36 in 2017 to 34 in 2019. The year the greatest number of publications was 2017 (n = 36). However, the number of publications remained constant (n = 34) from 2019 to 2021, with 2022 having the fewest (n = 29). In terms of the total number of papers published, 202 have been published since 2017, which shows an overall increase in publication rates compared to earlier years.

Table 1: Published articles by year

YEAR	Frequency
2022	29
2021	34
2020	34
2019	34
2018	35
2017	36

3.4 The Authors of the Document

In the Scopus citation database, a total of 159 authors published 202 documents on STEM education. Rawat, K.S., Yu, K.C., Hsiao, H.S., Lin, K.Y., Mangham, R.R., Megri, A.C., Monahan, J., Yu, K.C., Abiade, J., and Batts, T. are among the authors who have published more than one paper. 51 authors have published more than one paper in the Scopus citation database, while 108 authors wrote or co-wrote one paper; thus, most STEM studies were co-authored (See Figure 4).

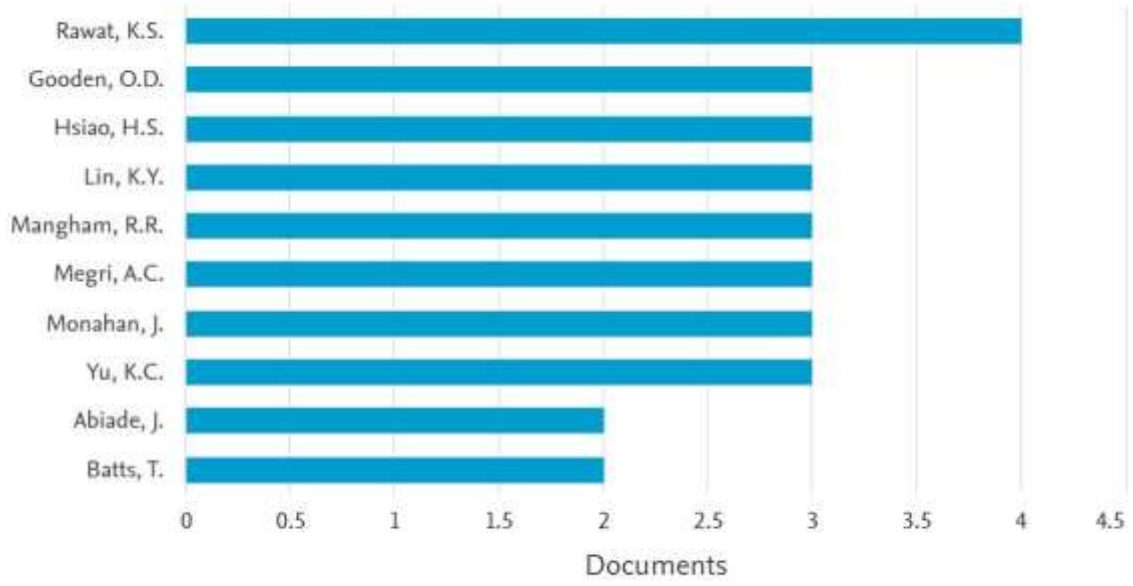

Fig. 4: Publications based on authors

3.5 The Countries of Published Documents

Figure 5 depicts the distribution of articles according to the country of implementation. The graph represents the 15 countries with the most papers published in the Scopus citation database. According to the figure, there is a significant difference in the rate of publication in the United States compared to all other countries. There were 109 publications in the United States: nine in Spain, eight in Taiwan, six in Italy, five in Israel, and four each in Brazil, China, Greece, and Malaysia.

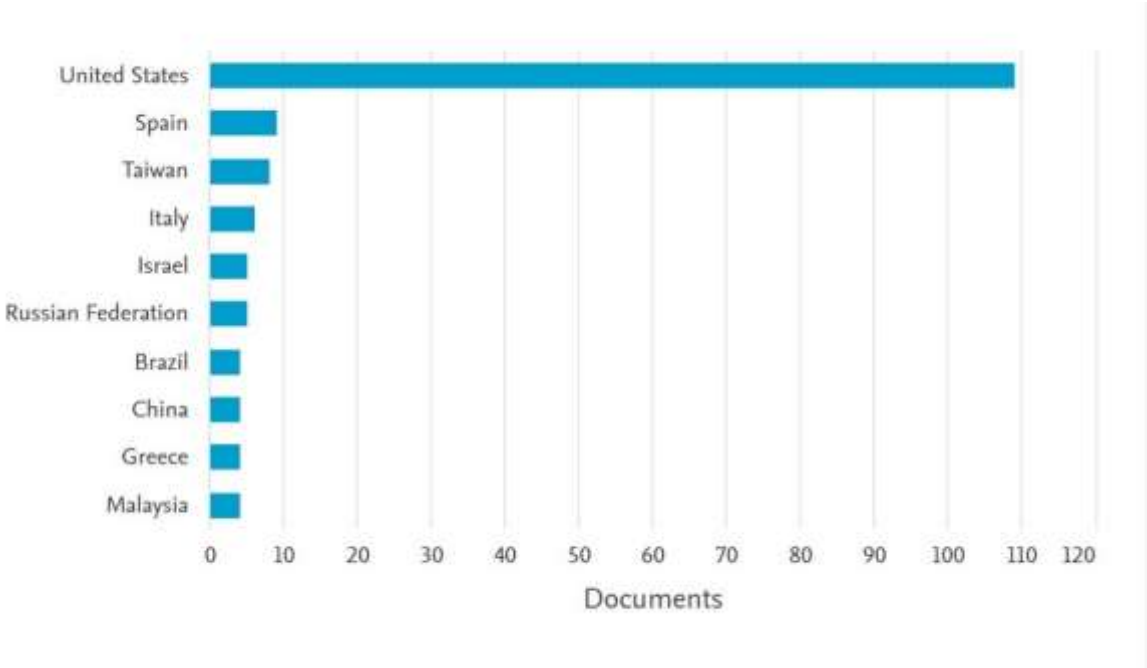

Fig. 5: Distribution of Articles According to Countries

3.6 Analysis of the Most Frequently Cited Documents

Publications with the most citations are recognized mainly by other scientists due to their study subjects and fields and because they provide more essential data about the relevant area for future research (Mamun et al., 2022). Thus, the highest citations were chosen based on the citation numbers of the first seven records

on STEM education in the Scopus citation database.

As shown in Table 1, the engineering discipline received the most citations in STEM education (Fan & Yu, 2017; n = 76), with an emphasis on how an integrative curriculum can benefit students in engineering design practices. The second-most-cited study publication was "Robotics and STEM learning: students' achievements in assignments according to the P3 Task Taxonomy—practice, problem-solving, and projects" (Barak & Assal, 2018; n = 71), which focuses on the impact of robotics on students' STEM education.

The third publication conducted by Vennix, Brok, and Taconis (2017), with an impressive amount of citations (n = 64), examines engagement activities developed by STEM-based educational organizations or universities in collaboration with higher education to inform and motivate students to pursue a career in STEM in the work context of science school.

The fourth publication that received high citations (Hsu et al., 2017; n = 57) was concerned mainly with using Augmented Reality (AR) technology to encourage medical surgery students to learn and investigate their perceptions of the AR lessons and simulators and their interest in STEM.

Furthermore, the fifth most frequently cited document (n = 20) carried out by Altan and Tan (2021) discussed how the creativity skills of high school students could be improved in science education. The purpose of their research was to integrate the process of design-based learning of real-life engineers in classroom applications to solve real-life problems, thus improving students' creative thinking skills in STEM education.

Table. 1: The most cited documents in the Scopus citation database

#	**Title**	**Authors**	**Publication Year**	**Source**	**Total Citation**
1	How an integrative STEM curriculum can benefit students in engineering design practices	Fan, S.-C., Yu, K.-C.	2017	International Journal of Technology and Design Education 27(1), pp. 107-129	76
2	Robotics and STEM learning: students' achievements in assignments according to the P3 Task Taxonomy—practice, problem-solving, and projects	Barak, M., Assal, M.	2018	International Journal of Technology and Design Education 28(1), pp. 121-144	71
3	Do outreach activities in secondary STEM education motivate students and improve their attitudes toward STEM?	Vennix, J., den Brok, P., Taconis, R.	2018	International Journal of Science Education 40(11), pp. 1263-1283	64
4	Impact of augmented reality lessons on students' STEM interest	Hsu, Y.-S., Lin, Y.-H., Yang, B.	2017	Research and Practice in Technology-Enhanced Learning 12(1),2	57
5	Concepts of creativity in design-based learning in STEM education	Bozkurt Altan, E., Tan, S.	2021	International Journal of Technology and Design Education 31(3), pp. 503-529	20

4. DISCUSSION AND CONCLUSION

A total of 202 articles were published regarding STEM education at the high school level. This study applied the content analysis method to find out what types of articles were published, in what subject area, in which country and year, by how many authors, and the frequency of the first five most-cited articles. The outcomes reveal that STEM education has emerged as an educational technology field, and almost 50% of articles were carried out in the field of engineering education. The majority of articles published in STEM education, almost 69%, are conference papers, 29% are journal articles, and the rest are published as books, reviews, or survey papers. Although the number of STEM education articles published has decreased from 36 in 2017 to 29 in 2022,

According to the results of the authors of the documents, 159 authors published 202 articles in the STEM education area, and the majority of them were from developed or rapidly developing countries such as the U.S., Spain, Taiwan, Italy, Israel, etc. Further, the outcome of the countries of published documents illustrates that 15 countries are actively working in the STEM education area; however, the U.S. has a significant number of publications (109 out of 202) among other countries. This is because the U.S. government has realized the great shortage of numbers in the workforce in the country; thus, they aim to encourage students to participate in all STEM-related activities, motivate them to choose STEM fields, and pursue STEM-related careers in the future (Ma & Ma, 2017).

According to studies, there is a social gender imbalance in STEM disciplines, which reduces when STEM education is fostered. The majority of the definitions of STEM, STEM education, and integrated STEM education are clarified in the literature studies.

Teachers' roles in science, technology, engineering, and mathematics classrooms are to communicate theoretical material to learners and to guide them toward higher-order thinking, innovation, and productivity levels. While ensuring this, they should turn the educational system into a learning atmosphere in which students are not afraid of making mistakes and are encouraged to develop their self-confidence. Teachers must also stay informed about the most recent educational trends, constantly developing scientific and technical developments (Bakanlığı, 2016). As a result, one crucial step is to modernize the educational process and institutions and design STEM-related activities to assist students in becoming lifelong learners.

5. RECOMMENDATIONS

Consistent with the studies reviewed, STEM education has the potential to define distinct skills and abilities and provide knowledge that will be useful in determining students' careers. Studies in the STEM area are usually conducted with science teachers. As a future study, similar research could be undertaken with teachers and teacher candidates from various professions. In addition, in STEM fields, there are significant inequalities between male and female students. As a result, it is suggested that studies be carried out to reduce disparities by motivating and encouraging females to pursue STEM-related careers. Moreover, studies regarding incorporating STEM applications into the curriculum could be designed to enhance STEM education teaching.

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