

Content Analysis of Studies Conducted on STEM Education from 2010 to 2020: Perspective of Emerging Technologies in Learning

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Abstract—The purpose of this study is to analyse the studies about science, technology, engineering and mathematics (STEM) education in the world by using the content analysis method and to reveal the trend in the field. In this study, which was carried out in a survey design to analyse the articles published in the Institute for Scientific Information web of science database between 2010 and May 2020 and to determine the research trends of the articles published in this direction, 100 articles selected by criterion sampling method were examined. In the selection of articles, attention was paid to include studies on ‘STEM Education’ with respect to perspective of emerging technologies in learning. After examining the articles, the articles were analysed by content analysis method. The articles were examined in terms of descriptive information about the identity of the article, category field, article subject area, method, sample, data collection tools, data analysis methods and discussion size. The research data were interpreted based on the percentage and frequency findings, and data were presented as tables and graphs. According to the research data, it was determined that the highest number of publications was published between 2016 and 2018, mostly studies with 2 authors were conducted, and almost all of them were written in English. In addition, it was determined that the number of hypotheses was mostly 2 or 3, and STEM education as a subject area was mostly handled covering all its dimensions, whereas mathematics and science education took second place. It was also observed that the experimental model and the mixed method were used extensively in the studies, and the written sources were frequently used as data collection tools. It was concluded that one-third of the sample level was primary education level studies, the sample selection method was purposeful sampling, and the discussion size was 3 or 4. Based on the current research analysis, the profile and trends of the articles were monitored and important recommendations were made in the framework contributing to scientific research.

Keywords—STEM, education, content analysis, mathematics

1 Introduction

Science, technology, engineering and mathematics (STEM) is an approach needed to emphasise the subjects of science, mathematics, technology and engineering in school settings starting from early childhood, and to develop 21st century skills of individuals, such as critical thinking, creativity, curiosity and cooperation [3] [16] [1] [9] [14] [18].

STEM is an acronym that refers to the education-related programmes in relevant disciplines. It refers to the STEM disciplines that were first put forward by the US National Science Foundation [12] [8]. It is an approach that aims to teach these disciplines as a principle and covers the entire process from early childhood to higher education [4]. Although some educators see STEM as an individual reflection of any of the STEM disciplines, there are educators who argue that it should be integrated as a whole. Developmentally, it includes engineering or problem-solving process skills that require appropriate use [16]. Although these are being introduced to children, activities and environments are important to make them apply their acquired concepts by combining with existing concepts, and to learn and apply new concepts by constructing themselves [20] [30].

It is recommended to apply the STEM approach, which has been very popular in recent years, starting from preschool years [15]. In other words, children need to be equipped with innovations that involve theoretical knowledge of basic sciences, such as physics, chemistry, biology and mathematics, blend them with technology and engineering, and add value to life [20] [24] [28]. Considering the national regulations, there are several disadvantages in curriculum development, teacher preparation and standard-setting in order to implement STEM education [1]. STEM is an important approach and studying STEM subjects starting from early childhood has been discussed by various researchers recently. Teachers believe that the open communication and teamwork environment can be enhanced by using emerging technologies. Pedagogical innovation and empowering educators are essential requirements for teaching with emerging technologies [10].

There are several studies in the literature on STEM applications in preschool and primary school. The majority of these studies state that STEM applications have a positive effect on young children [11] [13]. However, in some studies, the question ‘Should STEM applications be started in early childhood?’ is asked [12] [14]. Along with this, there are a few studies in the literature that compile studies of this type to reveal the general picture of the effect of early childhood STEM applications on children. Based on the aforementioned points, it is understood that studies that examine the effects of STEM practices on children in preschool and primary school need to be brought together and evaluated.

It explains the relationship and interconnection of general issues involved in the development of digital skills as an essential precondition for lifelong learning. While technology is changing faster than ever it is necessary to start with developing skills early in education with inclusion of appropriate examples for development of skills for digital citizenship. This includes formal education (from early learning to higher education),

with implications on curriculum development and educational policies. Even more important is an ongoing curriculum adaption in the field of teacher education and professional development. It includes rethinking the roles of teachers and learners and transforming the learning environment. New pedagogies are supporting individual learning strategies for knowledge development and self-directed learning. Since education systems are traditionally developing slowly, examples are presented for supplementing personalized learning with open pedagogy and integration of educational technologies. In higher education new tools and strategies offer a wider range of personalized learning opportunities [9] [29].

2 Objective and methods

Most of these studies state that STEM applications have a positive effect on young children [5] [9]. However, in some studies, the question ‘Should STEM applications be started in early childhood?’ is asked [11] [14]. Along with this, there are few studies in the literature that compile, bring together or combine studies of this type to reveal the general picture of the effect of early childhood STEM applications on children. Based on the foregoing, it is understood that studies that examine the effects of STEM practices in preschool and primary school on children need to be brought together and evaluated. The aim of this study is to analyze the articles published on STEM education in the Institute for Scientific Information (ISI) Web of Science (WoS) database between 2010 and May 2020 and to determine the research trends of the articles published in this direction.

2.1 Population and sample

The population of the research consists of studies on STEM education in the ISI WoS database on a global scale. The sampling method was not used in the study, and all studies published in ISI WOS database on STEM education between 2010 and May 2020 were reviewed. The reason why only the studies in the ISI W o S database are considered in the study is that it is one of the most widely used databases in the world. ‘FeTeMM and STEM’ keywords were used while reviewing the related literature. As a result of the review, 100 studies were found.

2.2 Data collection tools

Each article included in the study was analysed using the ‘Article Classification Table’. Tables in the research were created by using the ‘Article Classification Form’. In this form, the following features of the research were considered and tables and graphs were created accordingly:

- Year of publication
- Number of authors
- The number of hypotheses
- Publication language
- Research model
- Subject area
- Research method
- Data collection tool
- Sampling level
- Sample

2.3 Analysis of data

By scanning the ISI WOS database, studies examining STEM applications (STEM education) have been reviewed. 'FeTeMM and STEM' keywords were used while surveying the related literature. As a result of the review, a total of 100 studies published between 2010 and May 2020 were identified. These studies were analysed in the Microsoft Excel program, their frequency and percentage values were calculated, and the data were displayed in tables and graphics.

2.4 Validity and reliability

In order to ensure the validity of the study, the data were collected properly for content analysis and appropriate analysis methods were used. Studies are numbered to ensure that each run is represented once in the sample. The developed coding form is applied to all content analysis studies in the same way.

In order to ensure the reliability of the study, opinions of two experts were obtained to determine the reliability of the data. As stated above, there are eleven basic variables in the study. In the study, the Kappa parameter was used to calculate the reliability between coders, and it was found to be 0.92. It can be said that the reliability is excellent. According to Cohen (1988) this value is almost perfect as it is between 0.81 and 1.

3 Findings

In the findings section of the research, the findings and analysis of the studies conducted with STEM between 2010 and May 2020 were examined in terms of different variables. In this section, the distribution of the published studies by years, the number of authors, the publication language, the study model, the subject area of the study, the type of the study, the research methods used, the data collection tools, the sample level, the sample selection methods and the findings of the discussion in the study are included as dimensions. The research findings are shown as frequency and percentage results in tables and graphs which are interpreted in this direction.

As shown in Figure 1, the distribution of 100 studies examined between 2010 and May 2020 is given by years. The studies showed a steady increase between 2010 and

2018, and the highest number of studies was carried out between 2016 and 2018. After 2018, it is seen that there is a decrease in studies between 2019 and May 2020.

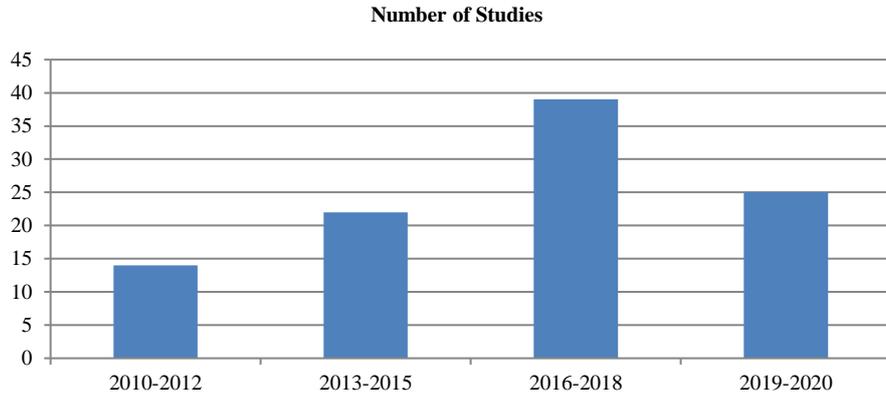


Fig. 1. Distribution of the number of STEM studies published between 2010 and May 2020 by years

From Table 1, we see that the studies with two authors are in the majority. These are followed by studies with one author and three authors that show an equal distribution. The minimum frequency is seen in studies with seven or more authors.

Table 1. Distribution of STEM studies published between 2010 and May 2020 by number of authors

Number of authors	F (frequency)
1	20
2	37
3	20
4	10
5	5
6	5
7 and above	3
Total	100

From Table 2, we see that 85% of STEM studies published between 2010 and May 2020 are in English, and the remaining 15% are in Turkish. 2. Distribution of STEM studies published between 2010 and May 2020 by study model

Table 2. Distribution of STEM studies published between 2010 and May 2020 by publication language

Publication language	F (frequency)
Turkish	15
English	85
Total	100

From Figure 2, we see that more than half of the studies use the experimental model, followed by document review, research, interview and content analysis with equal distribution.

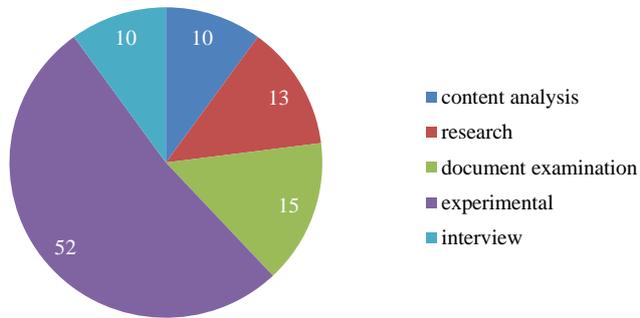


Fig. 2. Model of the Study

From Figure 3, it is seen that STEM generally includes all disciplines including STEM as a whole. The subject areas of other studies are listed as STEM–engineering.

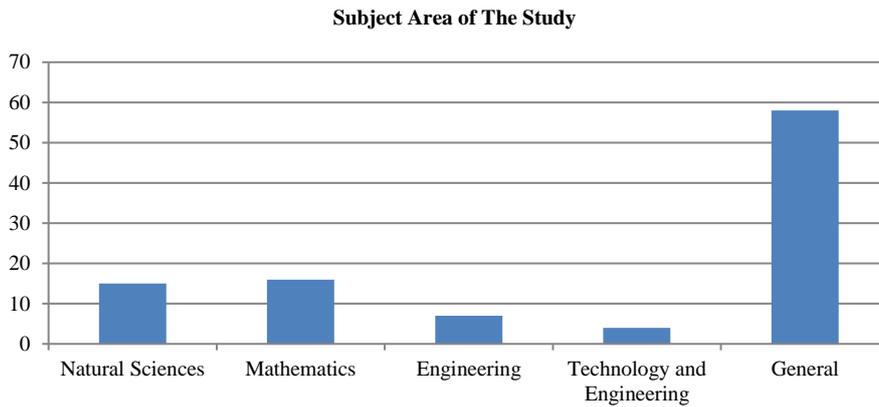


Fig. 3. Distribution of STEM studies published between 2010 and May 2020 by subject area

From Table 3, it can be seen that most of the STEM studies conducted between 2010 and May 2020 have been written as articles, followed by doctoral dissertations and master theses, respectively.

Table 3. Distribution of STEM studies published between 2010 and May 2020 by study type

Type of study	F (frequency)
Article	66
Master’s Thesis	12
PhD Thesis	22
Total	100

From Figure 4, it is seen that most of the studies on STEM are conducted with mixed method, while quantitative, qualitative and experimental design methods are used, respectively, in other studies.

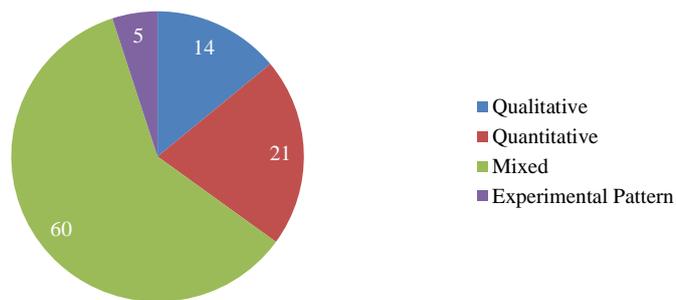


Fig. 4. Distribution of STEM studies published between 2010 and May 2020 by study method

From Figure 5, the data collection tools of studies on STEM are mostly written sources. It is seen that the data collection tools in other studies are distributed as questionnaire, observation form and interview form.

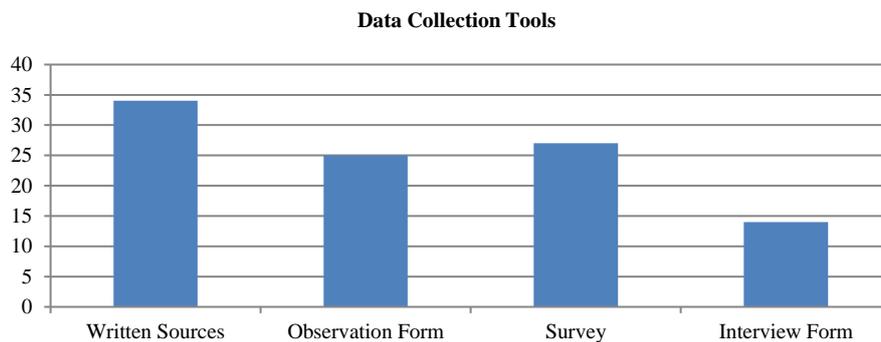


Fig. 5. Distribution of STEM studies published between 2010 and May 2020 by data collection tools

From Figure 6, we see that when the sample level in STEM studies is examined, there are 35 primary schools that are mostly selected. The selection of the sample level in other studies is distributed as secondary education, preschool and higher education.

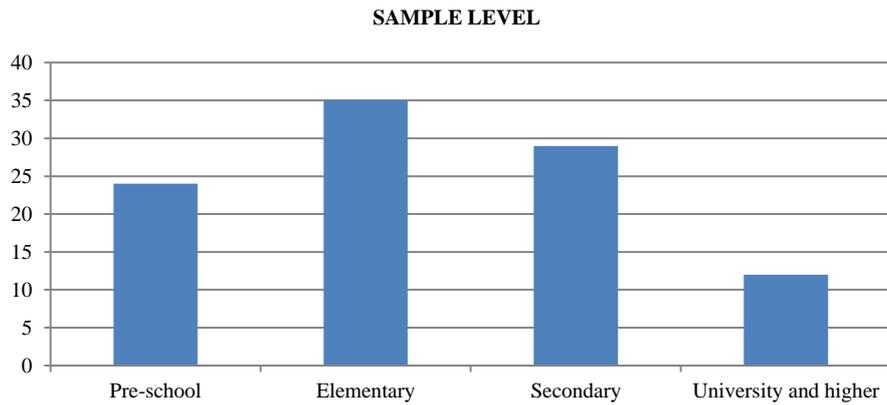


Fig. 6. Distribution of STEM studies published between 2010 and May 2020 by sample level

From Figure 7, we see that when the sample level in STEM studies is examined, there are 35 primary schools that are mostly selected. The selection of the sample level in other studies is distributed as secondary education, preschool and higher education.

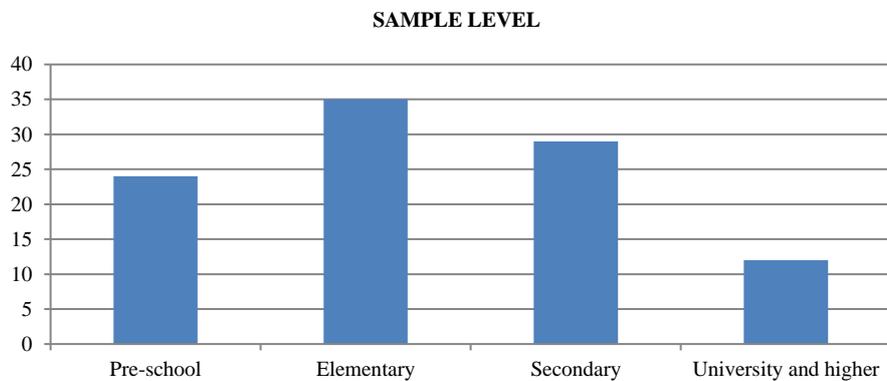


Fig. 7. Distribution of STEM studies published between 2010 and May 2020 by sample level

From Figure 8, it is seen that while purposeful sampling selection is made in 66 of the studies, 13 random sampling, 12 independent sampling and nine related sampling methods are distributed as selection forms in the remaining studies.

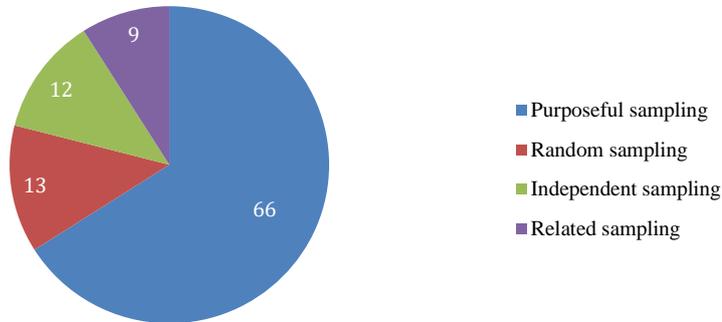


Fig. 8. Distribution of STEM studies published between 2010 and May 2020 by the sample selection method

From Table 4, we see that there are no studies with a discussion size of 1 among all studies reviewed. While it is seen that studies with a discussion size of 4 are in the majority, the discussion size of other studies is distributed as 2, 3, 5 and over 6, respectively.

Table 4. Distribution of STEM studies published between 2010 and May 2020 according to the size of discussion

Discussion size	F (frequency)
2	15
3	23
4	46
5	9
6 and above	7
Total	100

4 Discussion

In line with the studies examined, we see that Sagbas and Alkilinc [23] have are two-authored studies on STEM. Our research in Turkish is less than in English. When we look at the results in Sanli (2019) [26] and Sahin (2019) [25], we see that STEM education is handled in all dimensions. As in Tezer et al. (2019) [23] and other’s research, article review has a greater place than master thesis review. In addition to this, the sampling level is higher in the results we obtained, which can be seen in Bahsi (2019) [2] and Şanlı's [26] studies.

The development of new methodologies has involved a redefinition of the different educational agents’ performance, for the upcoming Horizon reports to generate radiography of the emerging technological trends that will have an impact in the upcoming years. As a consequence, we will focus on adaptative learning technologies based on the perspectives of profound learning, where the achievement of objectives will be reflected through generated learning analytics [18].

5 Conclusions

According to the research data, it was determined that the highest number of publications were between 2016 and 2018, most of the studies were two-authored, and almost all of them were written in English (85% English and 15% Turkish). In addition, it was determined that the number of hypotheses was mostly two or three, STEM education was handled with all dimensions of STEM education as a subject area, followed by mathematics and science education.

In addition, it was seen that the experimental model was used more than half of the studies 52% level, followed by document review, research, content analysis and interview model. It was observed that the mixed method was used extensively, as well as qualitative, quantitative and experimental design, and written sources were frequently used as a data collection tool.

It was determined that the studies were obtained from articles at 66% level, doctoral dissertations at 22% level, and master theses at 12% level. It was understood that almost half of the sampling level was primary education level, followed by secondary education, preschool, and university and above. It was concluded that the sample selection method was 66% purposeful sampling, and the discussion size was generally 3 or 4.

6 Recommendations

In this section, some suggestions that can contribute to the STEM education approach are discussed based on the findings obtained from the results of the studies. These are as follows:

- In-service courses should be given to teachers in STEM education so that they could improve themselves.
- STEM education should be given to children at an early age.
- STEM education should be applied to students of different age groups.
- When teachers prepare a course plan on STEM education, they should consider the development of students and arrange the classroom environment accordingly.
- Teachers and pre-service teachers should be gain awareness about providing efficiency in education by using technology in education consciously.
- Researchers from different fields should be in cooperation in STEM education applications.
- In STEM studies, research examining the difficulties faced by teachers and students should be conducted.
- In STEM studies, highly efficient results can be obtained by preparing an appropriate course plan and making the necessary planning.
- Students should take STEM education for the occupational fields needed and their awareness of those occupational areas should be developed.
- The effect of STEM education on exploring 21st century skills in students can be investigated.

- It can be ensured that STEM centres become more widespread and programs that will enable teachers and preservice teachers to develop themselves towards STEM education can be devised.
- Guidebooks that give instructions about STEM education can be prepared.

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