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Thematic Content Analysis of Doctoral Theses in STEM Education: Turkey Context

Ümmühan ORMANCI[1]

[1] Assist. Prof. Dr., Bursa Uludağ University, Bursa-TURKEY,ORCID ID: 0000-0003-3669-4537

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ABSTRACT

The aim of the study is to examine the doctoral theses in STEM education in Turkey in a comprehensive manner. Thematic content analysis method was used in the study. The data were obtained from the doctoral theses published until 2020 by examining CoHE National Thesis Center. As a result of the screenings, 30 doctoral theses were reached in the field of STEM education. Doctoral theses in the study were analyzed using the matrix. The data obtained was analyzed by using descriptive and content analysis method. In the findings obtained from the study, studies investigating the effect of STEM approach on academic success, understanding, scientific process skills and attitudes towards STEM are frequently encountered. In this context, it can be stated that studies have been carried out on the effects of STEM applications on both affective field, skill and cognitive field. However, when we look at the variables examined, it is generally understood that similar variables are studied. In this context, it is thought that studies on new variables, especially current skills in STEM education, will be important for the literature.

Keywords: STEM, doctoral theses, Turkey, thematic analysis.

INTRODUCTION

The information and behaviors that individuals should have change in parallel with the advancement in technology, individuals are expected to be individuals who are researching, questioning, and able to solve the problems they encounter and have high level thinking skills. Yıldırım & Selvi (2017) also states that it is important to raise individuals who have problem solving and critical thinking skills, think, question and produce scientific solutions to the problems they face. In parallel with this situation, the curriculum has been changed in many countries and the philosophy of the programs has shifted from behaviorism to constructivism (Güneş, Sağdıç & Şimşek, 2018). At this point, STEM started to be studied in the international arena in 1990s and in our country in 2010 (Çepni & Ormancı, 2018; Herdem & Ünal, 2018; Martín - Páez, Aguilera, Perales - Palacios & Vílchez - González, 2019). As Williams (2011) notes, science, technology, engineering and mathematics, which must be

Correspondence author e-mail: ummuhan45@gmail.com © ISSN:1304-6020

addressed in an integrated fashion in programs, have become more common and important lately, although they have been developed in some countries for at least thirty years. Because, considering the current economic and technological competition between countries, it is important to train students with STEM competence (Kalkan & Eroğlu, 2016).

The need for STEM education and skills stems from the changes in the global economy and labor force needs (Kennedy & Odell, 2014). Scientific and economic development and continuity of a country are associated with supporting STEM education and creating professional awareness in STEM (Bahar, Yener, Yılmaz, Emen & Gürer, 2018). As the world develops technologically, it can be said that the economy and power of a country are related to effective practices and potential of skilled workers in STEM fields (Çevik, 2018). In this context, in education systems where future engineers, scientists or technologists will be trained, STEM education, which is performed using 21st century skills, is gaining importance all over the world (Aslan-Tutak, Akaygün & Tezsezen, 2017). It can be said that effective teaching practices are closely related to the students' desire to take more courses in science, technology, engineering and mathematics and to choose the professions in which they can use their knowledge related to these fields in the future (Hacıömeroğlu, 2018). At this point, both primary and secondary classes are updated according to the STEM curriculum and pedagogy to satisfy the need for STEM literate employees (Margot & Kettler, 2019). In this context, the importance of every study and practice related to STEM education becomes apparent.

STEM is a statement that encompasses disciplines, leads to effective and quality learning, takes the knowledge that exists in nature and enables daily use, and includes military, economic, high-level thinking (Yıldırım & Altun, 2015). With STEM, it is aimed to raise individuals who can associate science, technology, engineering and mathematics with each other and develop innovative skills (Sümen & Çalışıcı, 2016). In this context, STEM education is an educational approach focusing on the interdisciplinary nature of science, technology, engineering and mathematics (Çalışıcı & Sümen, 2018). STEM education strives to fuse science, technology, engineering and mathematics disciplines by linking a unit or lesson with a real life problem and a content (Bozkurt Altan, Yamak & Invention Kırıkkaya, 2016). As will be understood, STEM education includes the knowledge, skills and beliefs created in cooperation at the intersection of more than one STEM subject area (Çorlu, Capraro & Capraro, 2014). STEM education is defined as an approach to teaching STEM content with two or more STEM domains linked to STEM practices in an original context in order to link issues to improve students' learning (Kelley & Knowles, 2016). However, while scientific research in STEM includes the formulation of a problem that can be answered through research; engineering design includes the formulation of a problem that can be solved through construction and evaluation in the post-design phase (Kennedy & Odell, 2014). Thus, STEM includes the interdisciplinary processing of the areas, subject or concept in a linked way.

With STEM education, students make sense of the new information they learn, present it to daily life or the environment they live in, and adapt (Timur & Inancli, 2018). The integration of STEM concepts and practices increases the conceptual learning within the disciplines and supports the objectives in engineering and technology (Gencer, Doğan, Bilen & Can, 2019). In addition, individuals who receive STEM education use the knowledge they have acquired in accordance with science and the nature of science in organizing the existing schemes (Yaman, Tungaç & İncebacak, 2019). As will be understood, STEM education has many positive effects on students' cognitive learning. In addition, integrated STEM education requires a lot of materials and resources for students to research solutions to real-world problems by designing, expressing, testing and reviewing their ideas (Stohlmann, Moore & Roehrig, 2012). As a result, STEM education is of great importance in terms of interdisciplinary learning of information, obtaining products with engineering applications and obtaining 21st century skills in the process of obtaining products (Akgündüz & Akpınar, 2018). In other words, thanks to STEM, students learn to solve problems in different disciplines and their individual development is supported in acquiring knowledge and skills (Akgündüz, 2016). STEM, based on an interdisciplinary approach, provides the development of competitiveness and STEM literacy of individuals (Bircan, Köksal & Tımbız, 2019). In addition, STEM education provides individuals with high-level thinking skills, creativity skills, understanding that a problem can have more than one solution, courage, self-confidence, collaboration and effective communication skills (Deveci, 2018). Since STEM develops various literacy skills, it creates a bridge for individuals to prepare for a career (Wu, Marsono & Khasanah, 2019). In this context, in addition to cognitive learning with STEM education, the acquisition of high-level skills expected from 21st century individuals is also supported.

Along with many positive contributions of STEM education, as stated by Eroğlu & Bektaş (2016), many countries aim to learn more about STEM and support all students with STEM education. Integrated approaches to STEM education are increasingly popular, but remain challenging (Shernoff, Sinha, Bressler & Ginsburg, 2017). As a result, we need to increase the number of successful students trained in STEM fields to avoid falling behind in this race (Çınar, Pırasa, Uzun & Erenler, 2016). In our country, there has been an increase in the number of studies on STEM application development, the effects of the STEM model in practice, developing a scale for measuring STEM skills and the opinions of teachers and students (Özbilen, 2018). Increasing interest in the subject day by day and the increase of scientific studies in this context reveals the necessity to summarize the topics examined in the researches and the results obtained (Özkaya, 2019). Because, it is necessary to analyze the studies, interpret the findings and accordingly draw conclusions about the field of deficiencies and what should be done in the field of implementation.

When the studies in the literature are examined, analysis studies on the biometric analysis of scientific research on STEM (Özkaya, 2019), meta synthesis (Herdem & Ünal, 2018), content analysis (Aydın-Günbatar & Tabar, 2019; Çevik, 2017; Kaleci & Korkmaz, 2018), review (Jayarajah, Saat, Rauf & Amnah, 2014; Tezel & Yaman, 2017; Yılmaz, Gülgün, Çetinkaya & Doğanay, 2018), analysis of qualitative findings (Kanadlı, 2019) and methodological analysis of STEM studies (Özcan & Karabaş, 2019) were carried out. Furthermore, analysis/ meta-analysis of STEM-related experimental studies (Belland, Walker, Kim & Lefler, 2017; van den Hurk, meelissen & van Langen, 2019; Yıldırım, 2016), meta-analysis of the impact of STEM on cognitive outcomes (Belland, Walker, Olsen & Leary, 2015) and meta-analysis of STEM-related studies (Kim, Belland & Walker, 2018) were conducted. In addition, by examining the studies in the field, the perceptions of teachers with STEM education (Margot & Kettler, 2019), how STEM is implemented (Henderson, Beach & Finkelstein, 2011; Martín - Páez et al., 2019; Thibaut et al., 2018), its effect on students' learning (Becker & Park, 2011), the use of augmented reality technology to support STEM learning (Ibáñez & Delgado-Kloos, 2018; Tekedere & Göke, 2016) and which teaching strategies are dominant in the implementation of integrated STEM education (McDonald, 2016; Mustafa, Ismail, Tasir & Said, 2016) was tried to be understood. Analysis of studies on pre-school STEM/STEAM education (Ata Akturk & Demircan, 2017), three-dimensional STEM education (Pellas, Kazanidis, Konstantinou & Georgiou, 2017), higher education STEM women's place (Blackburn, 2017) and STEM topic in teacher education (Kızılay, 2018) have been carried out in the field of literature. As will be understood, the analysis of STEM education, especially in the international literature, has been frequently conducted and continues to be done. Although studies in the literature are frequently analyzed in our country, it can be said that these studies are generally at a more general level. However, as stated by Martín - Páez et al. (2019), the STEM approach has been undergoing continuous development and change since its inception. At this point, it is thought that it is important to analyze the new studies done every 3-5 years. It is thought that more frequent analysis of recently popular and frequently studied topics, especially STEM, will contribute to the literature. When the studies conducted are examined, no study has been found in which the researchers' dissertations that they have been working for many years have been examined. Two studies aimed at determining the general orientation (Daşdemir, Cengiz & Aksoy, 2018) and method and subject tendency (Elmalı & Kıyıcı, 2017) were examined in the literature only by examining the post graduate theses and articles related to STEM. At this point, it is thought that this study will be important for the literature. The aim of this study is to examine the doctoral theses in STEM education in Turkey. Accordingly, the research questions in the study are as follows:

1. What are the aims of doctoral theses in STEM education?
2. What are the methods, sampling and data collection tools of doctoral theses in the field of STEM education?
3. What are the subjects /fields of doctoral theses in the field of STEM education?
4. What are the results of doctoral theses in STEM education?
5. What are the suggestions of doctoral theses in the field of STEM education?

METHODS

In this study, thematic content analysis method was used. In the thematic content analysis method, it is aimed to examine the in-depth studies by using a specific matrix and to present the summaries of the studies by determining the similarities and differences. In the study, it was found appropriate to use thematic content analysis method, since it was aimed to examine the doctoral theses on STEM education, to determine the points investigated and not researched, and to examine the results presented.

Within the scope of the study, theses in the CoHE National Thesis Center were examined. For this purpose, scans were made by writing the words "STEM", "science, technology, engineering, and mathematics" and "science-technology-engineering-mathematics" and their Turkish equivalents (“FeTeMM”, “Fen, teknoloji, mühendislik ve matematik” and “fen-teknoloji-mühendislik-matematik”) on the CoHE National Thesis Center website. Scanning was made using the interdisciplinary concept, but it was not included in the study since STEM related concepts were not directly included. As a result of the scans, many studies have been reached, some of which are studies containing the term stem, which is a term of biology. As a result of the researches and examinations, 30 doctoral theses were determined to be related to STEM and included in the study. Despite the researches, some of the doctoral theses in the STEM area may have been overlooked or not uploaded to the system, and this is the limitation of the research. The scans cover doctoral theses up to 2020. These studies are indicated in the bibliography section as (*).

The thematic analysis matrix developed by Ormancı Çepni, Deveci & Aydın (2015) was used for the purposes of the research by making necessary arrangements for the thematic analysis of the doctoral theses reached after the scans were made. There are two sections in the matrix, general and content features. The general features section contains information about the university where the thesis was published, the department in which it was done, the gender of the researcher and the year of publication. Findings regarding which universities the theses examined are in Table 1.

Table 1. *Distribution of theses according to published universities*

Code	f	%
Gazi University	7	23.3
Hacettepe University	3	10.0
Ondokuz Mayis University	3	10.0
Balıkesir University	2	6.7
Erciyes University	2	6.7
Gaziantep University	2	6.7
Necmettin Erbakan University	2	6.7
Aydın Adnan Menderes University	1	3.3
Bursa Uludağ University	1	3.3
Dokuz Eylül University	1	3.3
Eskişehir Osmangazi University	1	3.3
Istanbul University-Cerrahpaşa	1	3.3
Marmara University	1	3.3
Muğla Sıtkı Koçman University	1	3.3
Middle East Technical University	1	3.3
Pamukkale University	1	3.3
Total	30	100.0

When Table 1 is examined, it is understood that 23.3% of theses are done at Gazi University. In addition, 1.0% of theses were done at Hacettepe University and Ondokuz Mayıs University. In addition, it was determined that 6.7% of theses on STEM were done at Balıkesir University, Erciyes University, Gaziantep University, or Necmettin Erbakan University. The distribution of the theses examined according to the departments in which they are done is as shown in Table 2.

Table 2. *Distribution of theses according to departments*

Code	f	%
Science education / teaching	16	53.3
Primary education	5	16.7
Education programs and teaching	5	16.7
Classroom education	2	6.7
Mathematics education	1	3.3
Preschool education	1	3.3
Total	30	100.0

When Table 2 is analyzed, it is understood that 53.3% of theses are done in science education / teaching department. In addition, it has been determined that 16.7% of theses on STEM are done in primary education or education programs and education. The distribution of the researchers who conducted the theses on STEM according to their gender is given in Table 3.

Table 3. *Gender distribution of researchers who conducted the theses*

Code	f	%
Female	17	56.7
Male	13	43.3
Total	30	100.0

Looking at Table 3, 56.7% of the theses examined were done by female and 43.3% by male researchers. The distribution of the theses analyzed according to the years of publication is as shown in Table 4.

Table 4. *The distribution of the theses analyzed according to the years of publication*

Year	f	%
2016	3	10.0
2017	4	13.3
2018	12	40.0
2019	11	36.7
Total	30	100.0

When Table 4 is examined, two theses were made in 2016, thee theses in 2017, 12 theses in 2018 and 10 theses in 2019. At this point, it can be stated that the number of theses gradually increased over the years. In the content part, which is the second part of the matrix used in the study, the purpose, method, universe-sample / study group size and level characteristics, data collection tools, topics /areas, result and suggestion data of studies are included. The data in the method and subject part of the obtained data were analyzed using descriptive analysis, and the data in the purpose, result and suggestions part were analyzed using the content analysis method. In the content analysis process, the data obtained from the studies were first converted into codes and the appropriate codes were brought together and categories were created. Frequency and percentage values for the codes and categories created were calculated and presented in the findings section.

FINDINGS

In this part of the study, the findings related to the content characteristics of the theses examined within the scope of the research are included. In this context, this section includes the findings about the purpose, method, sample / study group, data collection tools, subject, result and recommendation of the study.

What are the purposes of the doctoral theses on STEM?

The distribution of theses on STEM according to their purposes is as given in Table 5.

Table 5. *The distribution of theses on STEM according to their purposes*

	Category	Code	f	%	f	%
The effect of STEM applications	Effect on skill size	Effect on scientific process skills	6	5.8	28	26.9
		Effect on scientific creativity	5	4.8		
		Effect on problem solving skills	4	3.9		
		Effect on critical thinking	3	2.9		
		Effect on life or 21st century skills	2	1.9		
		Effect on environmental literacy	1	0.96		
		Effect on mathematical reasoning skills	1	0.96		
		Effect on engineering skills	1	0.96		
		Effect on reflective thinking skills	1	0.96		
		Effect on psycho-motor skills	1	0.96		
		Effect on social product reveals	1	0.96		
		Effect on presentation skills	1	0.96		
		Effect on team work	1	0.96		
	Effect on the affective domain	Effect on attitudes towards STEM	6	5.8	26	25.0
		Effect on perceptions / interests of STEM fields	3	2.9		
		Effect on attitudes towards science course	2	1.9		
		STEM effects on career interests	2	1.9		
		Effect of science on the views of nature	1	0.96		
		Effect on motivation towards science	1	0.96		
		Effect on mathematics interests	1	0.96		
		Effect on attitudes towards mathematics	1	0.96		
		Effect of mathematics on self-efficacy perceptions	1	0.96		
		Effect on beliefs towards solving mathematical problems	1	0.96		
		Effect on perceptions towards engineers and engineering	1	0.96		
		Effect of interrogative learning skills perceptions	1	0.96		
		Effect on attitudes towards socio-scientific subjects	1	0.96		
		Effect on self-efficacy beliefs for STEM education	1	0.96		
		Effect on STEM interests	1	0.96		

		Effect on STEM motivations	1	0.96		
		Effect on attitudes towards 21st century education	1	0.96		
	Effect on cognitive domain	Effect on academic achievement / understanding in science / mathematics / astronomy	12	11.5	17	16.4
		Effect of information on permanence	1	0.96		
		Effects on environmental mental models	1	0.96		
		Effect on learning strategies	1	0.96		
		Effect on their understanding of career awareness in STEM fields	1	0.96		
		Effect of STEM trainings to reflect their qualifications	1	0.96		
Determining the case	Determining the case regarding the application process	Examining the activities process and applications	4	3.9	17	16.4
		Development of STEM applications	4	3.9		
		Examination of the suitability of the activities for STEM education and the quality of the products	2	1.9		
		Comparison of robotic assisted STEM applications made with simple / cheap materials	1	0.96		
		Examining the course design process	1	0.96		
		Determination of in-class STEM integration applications	1	0.96		
		Understanding how classroom practices are realized through self-examination method	1	0.96		
		Examining the characteristics of STEM education	1	0.96		
		Developing and implementing STEM in-service training program	1	0.96		
		Designing a STEM-based family participatory design curriculum	1	0.96		
	General case determination	Revealing the views on STEM and STEM education	5	4.8	16	15.4
		Determination of perceptions about STEM integration	3	2.9		
		Determination of career interests in STEM fields	2	1.9		
		Determining STEM skills used by students	1	0.96		
		Examination of motivations for STEM fields	1	0.96		
		Determination of the relationship between career interests and motivations for STEM fields	1	0.96		
		Determination of attitudes towards STEM areas	1	0.96		
		Presenting a model for the relationship between career interests and motivations for STEM fields	1	0.96		
		Determination of STEM integration self-efficacy perceptions	1	0.96		
Total			104	100.0	104	100.0

* Since there are more than one purpose in some studies, the number is different.

When Table 5 is analyzed, it is understood that the studies conducted are 68.3% on the effect of STEM applications and 31.8% on determination. In the theses conducted, the effect of the STEM approach was investigated at 11.5% academic achievement / understanding, 5.8% scientific process skills and 5.8% attitudes towards STEM. Doctoral theses at this point were made on the effect of STEM approach on 26.9% skill, 25.0% affective domain, and 16.4% on cognitive domain. As can be understood, it can be stated that studies investigating the effects on both affective domain, skill and cognitive field were conducted in STEM theses. In doctoral theses on STEM, it is aimed to reveal their views about STEM / STEM education 4.8% and 3.9% often to examine the effectiveness process and applications or to develop STEM applications. In this context, it can be stated that there are also studies on determination, but their number is low.

What are the methods, sampling and data collection tools of doctoral theses on STEM?

The distribution of doctoral theses on STEM according to the methods is given in Table 6.

Table 6. *The distribution of doctoral theses on STEM according to the methods*

Category	Code	f	%	f	%
Mixed method	Embedded design	10	33.3	20	66.7
	Mixed method	5	16.7		
	Convergent parallel design	3	10.0		
	Multiphase design	1	3.3		
	Educational design research method	1	3.3		
Qualitative method	Action research	4	13.3	8	26.7
	Design based research methodology	2	6.7		
	Holistic single case design	1	3.3		
	Qualitative research method	1	3.3		
Quantitative method	Correlational research design	1	3.3	2	6.7
	Semi-experimental design	1	3.3		
Total		30	100.0	30	100.0

When we look at Table 6, it is understood that mixed method is used in 66.7% of the studies, qualitative method in 26.7% and quantitative method in 6.7%. At this point, it can be stated that the mixed method is preferred in the majority of theses and this is a positive step in terms of the quality of doctoral theses. In the theses, embedded design were used in 33.3%, mixed method in 16.7% and convergent parallel design in 11.1%. In addition, 13.3% of doctoral theses on STEM were used for action research and 6.7% for design-based research methodology. The distribution of doctoral theses on STEM according to sample / study group types are given in Table 7.

Table 7. *Distribution of theses examined by sample/ study group types*

Category	Code	f	%	f	%
Student	Preschool children	3	7.5	23	57.5
	Fourth grader	1	2.5		
	Fifth grader	2	5.0		
	Sixth grader	1	2.5		
	Seventh grader	7	17.5		
	Eighth grader	1	2.5		
	Middle school science & arts center student	3	7.5		
	Ninth grader	1	2.5		
	Tenth grader	1	2.5		
	Eleventh grader	1	2.5		
	Different level high school students	2	5.0		
Teacher candidate	Science teacher candidate (2. class)	1	2.5	5	12.5
	Science teacher candidate (3. class)	3	7.5		
	Primary school teacher candidate (2. class)	1	2.5		
Teacher	Preschool teacher	2	5.	11	27.5
	Classroom teacher	1	2.5		
	Science teacher	2	5.0		
	ICT Teacher	1	2.5		
	Math teacher	1	2.5		
	Chemistry teacher	1	2.5		
	Vocational High School teacher	1	2.5		
	Institution manager	1	2.5		
	Lecturer	1	2.5		
Unreachable		1	2.5	1	2.5
Total		40	100.0	40	100.0

* The number is different because some studies were conducted with more than one study group.

When Table 7 is examined, theses in STEM education were conducted with 57.5% students, 27.5% teachers and 12.5% teachers. Also, in studies conducted with students, it is seen that thesis studies are carried out mostly with seventh grade students, and then with preschool children and middle school science and art center students. In the context of teacher candidates, third grade science teacher candidates were preferred the most. The distribution of the theses analyzed according to the sample / study group numbers is as shown in Table 8.

Table 8. Distribution of theses examined according to the sample / study group numbers

Code	f	%
0-10	2	6.7
11-30	3	10.0
31-50	8	26.7
51-70	5	16.7
71-100	7	23.3
101-200	2	6.7
1500 and above	2	6.7
Unreachable	1	3.3
Total	30	100.0

When we look at Table 8, it is understood that 26.7% of theses on STEM are done with 31-50 people and 23.3% with 71-100 people. In addition, it was determined that 16.7% of the analyzed studies were continued with 51-70 people and 10.0% with 11-30 people.

The distribution of doctoral theses on STEM according to data collection tools is given in Table 9.

Table 9. *Distribution of theses examined according to data collection tools*

Category	Code	f	%	f	%
Qualitative data collection tools	Semi-structured interview form	14	7.7	45	24.6
	Observation	11	6.0		
	Interview	10	5.5		
	Student journal	7	3.8		
	Focus group interview	3	1.6		
Scales	Attitude scale	12	6.6	37	20.2
	Interest scale	6	3.3		
	Perception scale	5	2.7		
	Motivation scale	3	1.6		
	Critical thinking scale	3	1.6		
	Awareness scale	2	1.1		
	Self-concept scale	1	0.6		
	Behavior scale	1	0.6		
	Belief scale	1	0.6		
	Paradigm scale	1	0.6		
	Problem solving skill scale	1	0.6		
	Semantic scale	1	0.6		
Surveys / forms	Evaluation form / survey	12	6.6	30	16.4
	Opinion survey	5	2.7		
	Information form	3	1.6		
	Open-ended questionnaire	2	1.1		
	Self assessment form	2	1.1		
	Problem solving skill measurement tool	2	1.1		
	Needs analysis form	1	0.6		
	Profession selection inventory	1	0.6		
	Process monitoring form	1	0.6		
	Design form	1	0.6		
Tests	Achievement test	13	7.1	28	15.3
	Creativity test	5	2.7		
	SPS test	4	2.2		

	Knowledge test	2	1.1		
	PSS test / inventory	2	1.1		
	Reflective thinking test	1	0.6		
	Figure test	1	0.6		
Documents	Student materials / products	5	2.7	27	14.8
	Document	5	2.7		
	Field / field notes	4	2.2		
	Working papers	4	2.2		
	Lesson plans	3	1.6		
	Events / modules developed	3	1.6		
	Resume	2	1.1		
	Notebooks	1	0.6		
Other data collection tools	Drawing	4	2.2	15	8.2
	Photo	3	1.6		
	Rubrics	3	1.6		
	Video	3	1.6		
	Word association test	1	0.3		
	Control list	1	0.6		
Unreachable		1	0.6	1	0.3
Total		183	100.0	183	100.0

* Since some studies have more than one data collection tool, the number is different.

When Table 9 is examined, it is seen that many different data collection tools such as interview, observation, test, materials, word association test are used in doctoral theses about STEM. In the studies conducted, it can be stated that qualitative data collection tools are used 24.6%, scales 20.2%, questionnaires / forms 16.4%, tests 15.3%, documents 14.8% and other data collection tools 8.2%. In the analyzed studies, semi-structured interview was used with 7.7% frequency, achievement test with 7.1% frequency, evaluation form / survey or attitude scale with 6.6% frequency and observation with 6.0% frequency. As a result of the analyses, it is observed that more than one data collection tool is often used in the same study.

What are the subjects / fields of doctoral theses on STEM?

The distribution of doctoral theses on STEM according to study subjects / fields is given in Table 10.

Table 10. *Distribution of theses examined according to their subject / field*

Category	Code	f	%	f	%
STEM fields	STEM topics / events	5	16.1	13	41.9
	Science practices lesson	3	9.7		
	Science and mathematics topics	2	6.5		
	Astronomy	1	3.2		
	Environmental issues	1	3.2		
	Math module	1	3.2		
Units	Electricity in our life / Electric energy	4	12.9	10	32.3
	Atom and periodic table	1	3.2		
	Let's visit the world of living things	1	3.2		
	Light and sound	1	3.2		
	Force and motion	1	3.2		
	Simple machines	1	3.2		
	Quadratic equation functions	1	3.2		
General concepts		5	16.1	5	16.1
Undergraduate courses	Science teaching and laboratory applications	1	3.2	3	9.7
	Basic math 2	1	3.2		
	Special teaching methods 1	1	3.2		
Total		31	100.0	31	100.0

* Since some studies have more than one subject, the number is different.

It can be stated that the study subjects / fields, which are another variable investigated within the scope of the study, are 41.9% frequent STEM areas, 32.3% frequently units, 16.1% often general concepts and 9.7% often undergraduate courses. In doctoral theses, it is seen that STEM subjects / activities are studied with 16.1% frequency, electricity / electrical energy in our life with 12.9% frequency and 16.1% with general concepts.

What are the results of doctoral theses on STEM?

The findings regarding the results obtained from doctoral theses on STEM are given in Table 11.

Table 11. *Distribution of theses examined according to the results*

		Code	f	%	f	%
STEM positive effects	Skill	Improving problem solving skills	5	6.3	21	26.3
		Improving scientific creativity skills	4	5.0		
		Improving scientific process skills	3	3.8		
		Improving critical thinking skills	3	3.8		
		Developing scientific process engineering skills	1	1.3		
		Improving mathematical reasoning skills	1	1.3		
		Having a positive effect on social product presentation	1	1.3		
		Having a permanent effect on social product team works	1	1.3		
		Positive effect on reflective trend levels	1	1.3		
		Developing 21st century skills	1	1.3		
	Affective	Increased perceptions / interests in STEM fields	6	7.5	19	23.8
		Increased attitudes towards STEM / STEM areas	4	5.0		
		Improving mathematics / socio-scientific / environmental attitudes	3	3.8		
		Increasing career motivations / interests in STEM fields	2	2.5		
		Having positive effects on academic self-perceptions	1	1.3		
		Improving their perception towards engineering profession	1	1.3		
		Increasing STEM awareness more	1	1.3		
		To cause a significant increase in attitudes towards 21st century education	1	1.3		
	Cognitive	Increasing academic achievements / understanding of science / mathematics / environment / astronomy	11	13.8	13	16.3
		Increased permanence	1	1.3		
		Increasing engineering knowledge levels	1	1.3		
	Behavioral	Having a positive effect in terms of thoughts about the nature of science	1	1.3	5	6.3
		Environmentally friendly behavior development	1	1.3		
		Improve psycho motor skills	1	1.3		
		Having a positive effect on social product production	1	1.3		
		Increased willingness to choose professions in STEM fields	1	1.3		
Application process	Practitioner	Teachers enrich STEM activities with their own knowledge and experience.	1	1.3	6	7.5
		Successfully transferred skills and competences to the classroom environment	1	1.3		
		Teachers have STEM gains	1	1.3		
		While all of the faculty members are familiar with the STEM education approach, most of the teachers and most of the teacher candidates do not know the approach.	1	1.3		
		Teachers had problems in technology and engineering in the planning and implementation of activities, but they did not have any problems in science, mathematics and arts.	1	1.3		
		Pre-service teachers need education regarding STEM education	1	1.3		
	Variables	STEM activities are carried out more efficiently as the socio-economic level increases.	1	1.3	3	3.8
		In STEM activities, BİLSEM students performed higher than science teacher candidates.	1	1.3		
		Having difficulties in implementing STEM activities in crowded classrooms	1	1.3		

Student	Students use their reasoning, problem solving, association, engineering, innovation, creativity, communication and cooperation, life and career skills in activities	1	1.3	2	2.5
	Providing various contributions to the participants	1	1.3		
No STEM effect	There is no significant difference in their attitude towards science	2	2.5	8	10.0
	There is no significant difference in scientific process skills	1	1.3		
	There is no significant difference in interrogative learning skills	1	1.3		
	STEM does not develop significantly in learning strategies	1	1.3		
	It is limited in developing scientific creativity skills	1	1.3		
	Students do not significantly improve their academic achievement in science lesson.	1	1.3		
	There is no significant difference in motivation levels	1	1.3		
Relationship between STEM and variables	STEM integration perceptions focus on solving real-life problems, implementation and engineering design process	1	1.3	3	3.8
	Class level, gender, parental education levels and the family's monthly income affect the career interest and motivation of students in STEM.	1	1.3		
	Career preferences of students regarding STEM fields vary significantly according to the type of school they study, gender and grade level.	1	1.3		
Total		80	100.0	80	100.0

* Since more than one result was reached in some studies, the number was different.

When Table 11 is examined, it can be seen that the results of the theses on STEM are obtained in terms of the positive effects of STEM 72.7%, the application process of 13.8% frequency, the lack of STEM effect of 8.0%, and the relationship between STEM and variables frequently with 3.8%. It can be said that the results regarding the positive effects on STEM are 26.3% skill, 23.8% affective domain, 16.3% cognitive domain and 6.3% behavioral. In the theses examined, STEM applications increased their academic/ academic/ academic achievements/ understanding 13.8% frequently, 7.5% frequently increased their perception/ interest in STEM fields, 6.3% frequently developed problem-solving skills, 5.0% frequently developed scientific creativity skills or increased the attitudes towards the STEM fields. In addition to this, it was concluded that STEM applications developed scientific process skills or critical thinking skills with a frequency of 3.8%.

What are the suggestions of doctoral theses on STEM?

The distribution of doctoral theses on STEM according to the suggestions is given in Table 12.

Table 12. *Distribution of theses examined according to the suggestions*

Category	Code	f	%	f	%
Studies that can be done	Studies should be done in different learning areas / branches	5	16.1	14	45.2
	Long-term studies should be done	4	12.9		
	Studies should be done at different grade levels / departments	2	6.5		
	Should be repeated with a larger group	1	3.2		
	New studies should be done and compared	1	3.2		
	STEM career training applications should be designed, and their effects should be tested	1	3.2		
Practical oriented	STEM education should be integrated more into training programs and lessons	2	6.5	9	29.0
	Collaborative studies should be done with branch teachers.	2	6.5		
	STEM activities should be included in science and arts center, school and out-of-school learning environments.	1	3.2		
	STEM education should be expanded in vocational high schools	1	3.2		
	Question structures regarding the current examination system should be aligned with STEM based activities	1	3.2		
	Brochures containing information on STEM professions should be prepared	1	3.2		

	Activity books used in science and art centers should be enriched in terms of STEM activities	1	3.2		
Teacher training	Compulsory or elective courses on STEM should be given in education faculties	3	9.7	6	19.4
	In-service trainings and seminars should be given	2	6.5		
	Self-examination method applications should be included	1	3.2		
Unreachable		2	6.5	2	6.5
Total		31	100.0	31	100.0

* Since there are more than one suggestion in some studies, the number is different.

When Table 12 is examined, in the doctoral theses about STEM, 45.2% of the suggestions were for future studies, 29.0% of were for practice-oriented and 19.4% of were for teacher trainings. In doctoral theses, 16.1% suggested that studies should be performed in different learning areas/ branches, 12.9% suggested that long-term studies should be performed and 6.5% suggested that studies should be performed at different grade levels/ departments. Furthermore, as regards the implementation process, 6.5% frequently suggested that STEM education should be further integrated into education programs and courses and 6.5% often suggested collaborative work with branch teachers is included in the theses. In the doctoral theses, 9.7% recommended that compulsory or elective courses should be given in STEM and 6.5% recommended that in-service trainings and seminars should be given.

DISCUSSION and CONCLUSION

In the findings obtained from doctoral theses on STEM in Turkey, more than half of the theses were based on the effect of STEM applications and less than half were based on situational/case studies. In this context, it is a good situation for the studies to be experimentally weighted, that is, on determining the effect. Because, despite the fact that the situation has been determined, no application can be made for the solution in these studies. However, with the applications carried out in experimental studies, it is tried to find solutions to existing problems. In parallel with the findings obtained, another point to be considered is that all of the studies examined are doctoral theses. What is expected in doctoral theses is that it is a unique study and can find a solution to a problem in the field. In this context, experimental or application-oriented studies can be expressed as an expected situation. In the theses examined in this study, researchers studying the effect of STEM approach on academic success/ understanding (Hebebci, 2019; Özçakır Sümen, 2018; Yıldırım, 2016), scientific process skills (Saçan, 2018; Taştan Akdağ, 2017) and attitudes towards STEM (Gülhan, 2016) were frequently encountered. In this context, it can be stated that there are studies examining the effects on both affective domain, skill and cognitive domain in the STEM theses examined. At this point, it is a situation that can be considered as a contributor to the field, that studies on different fields and features have been carried out. However, when we look at the variables examined, it is seen that similar variables are generally studied. While there are many variables that need to be studied and related to STEM, the fact that similar purposes have frequently been chosen may pose a problem in terms of originality of the studies. At this point, there are many variables in skill dimension, and it is thought that it will be important to focus on 21st century skills, especially those related to STEM. In the doctoral theses examined within the scope of the research, practical processes such as examining the effectiveness process and applications (Dönmez, 2018), developing STEM applications or revealing their views on STEM/STEM education (Kuvaç, 2018) were also found to be involved. In this context, it can be stated that there are also studies on case determination, but their number is low.

When we look at the results of the methods of doctoral theses on STEM, it is understood that mixed method is preferred in more than half of the studies. Embedded design (Ayverdi, 2018; Eroğlu, 2018), mixed method (Acar, 2018; Karakaş, 2017) and convergent parallel design (Kırıktaş, 2019) are frequently preferred in the theses examined. At this point, choosing the mixed method in the majority of theses shows that comprehensive/ detailed data are collected and analyzed based on both qualitative and quantitative research processes for the purpose of the research. The embedded design, which is included in the mixed method and based on supporting the experimental design with qualitative data, was the most preferred design. Qualitative method was used in some of the analyzed doctoral theses and quantitative method was used in a few. Similarly, Çevik (2017) and Kaleci & Korkmaz (2018) found that the studies based on qualitative method were the most common in the studies investigated in their study. It is concluded that action research (Hacıoğlu, 2017) and design-based research methodology (Gül, 2019) are frequently preferred in the doctoral theses analyzed. It can be said that determining a problem in both types of research and including the processes of finding and applying solutions to that problem increases the values of the studies. In the doctoral theses examined in this context, it can be said that longer-term and comprehensive methods are preferred in terms of method.

When we look at the sample/ study group types of doctoral theses on STEM, it was determined that more than half of them were conducted with students (Kızılay, 2018; Şen, 2018), then with teachers (Uştu, 2019) and less with teacher candidates (Türk, 2019). In addition, it is seen that thesis studies are mostly done with seventh grade students, then preschool children and then secondary school science and art center students. In addition, pre-school and science teachers are preferred in the studies conducted with teachers, whereas in terms of teacher candidates, studies with the third-grade science teacher candidates were carried out. In this context, the fact that it has been studied with all the relevant groups and the most secondary school students shows that STEM education is being worked with a group that is expected to contribute, and this situation can be evaluated as contributing to the field. In the studies examined in the literature review conducted by Kaleci & Korkmaz (2018), it was determined that the most research was carried out with primary school students. In the theses analyzed has been determined that the highest number of studies in the theses on STEM were conducted with 31-50 people (Hiğde, 2018; Koçyiğit, 2019), then 71-100 people, then 51-70 people (Ata Aktürk, 2019) and 11-30 people (Tunç, 2019).

Qualitative data collection tools, scales, questionnaires/ forms, documents, tests were used in STEM doctoral theses examined within the scope of the study. Semi-structured interview (Uştu, 2019), achievement test (Doğan, 2019), evaluation form / questionnaire (Türk, 2019), attitude scale (Kırıktaş, 2019) and observation (Gülen, 2016) were frequently used in the theses analyzed. In this context, it can be said that many different data collection tools such as interview, observation, test, materials, word association test are used in doctoral theses about STEM. It can be stated that this is a positive result both in terms of originality and usefulness of the studies and differences in data collection tools. Especially in many studies, it was determined that more than one data collection tool is used. In this case, it is thought that the studies are important in terms of supporting the validity and reliability processes.

When we examine the findings related to the study topics/ fields of doctoral theses on STEM, theses on STEM topics/ activities (Hiğde, 2018; Şen, 2018), electric in our life/ electrical energy topic (Taştan Akdağ, 2017) and general concepts (Kızılay, 2018) appears to be realized. At this point, it is seen that some studies in STEM sub-disciplines have been carried out. However, one of the points to be considered here is whether the practices or activities related to STEM are in a single field or interdisciplinary. In other words, in a study in which STEM activity related to a unit in science course is developed and applied, whether this activity covers only the science part of STEM or whether a relationship with other disciplines has been established should be examined. The necessity of conducting a new study on this and whether the activities developed/ applied are appropriate for STEM and whether inter-disciplinary relations have been established should be investigated.

According to the findings obtained from the study, the results regarding the positive effects of STEM applications were mostly obtained in doctoral theses. Results on the positive effects of STEM have often been found to show increased academic achievement/ understanding in science/ mathematics/ environment/ astronomy (Acar, 2018; Doğan, 2019), increased perceptions/ interest in STEM fields (school, 2019) and improved problem solving skills (Koç, 2019). In addition, results were reached that STEM applications improved scientific creativity skills (Hacıoğlu, 2017), increased attitudes towards STEM/ STEM fields (Pekbay, 2017), improved scientific process skills (Başaran, 2018) and critical thinking skills (Hebebci, 2019). Similarly, as a result of the compilation study conducted by Herdem & Ünal (2018), it was concluded that STEM education has a positive effect on students' academic achievement, scientific process skills and career awareness. It was determined that the results were in line with the purposes and that the participants improved their academic achievement and understanding in parallel with the most studied topic. In addition, it has been determined that STEM applications have positive effects in terms of many variables, and in very few studies, it has no effect. In this context, it can be stated that the use of STEM applications in classroom environments is positive and can often be included. In addition, meta-analysis studies can be performed for highly studied variables such as academic achievement, attitude, and scientific process skills. In the results obtained within the scope of this study, positive views on STEM practices such as the fact that teachers enrich their own knowledge and experience with STEM activities (Dönmez, 2018) and successfully transfer skills and competencies to classroom environment (Başaran, 2018) were reached. In this context, in addition to the effects of the implementation process, the results of the implementation process are included.

When we look at the findings related to the suggestions of the doctoral theses on STEM, suggestions such as studies in different learning areas / branches should be done (School, 2019), long-term studies should be done (Hacıoğlu, 2017) and studies in different grade levels / departments should be done (Acar, 2018) were made frequently. In this context, suggestions regarding future studies by researchers are often preferred. In addition, it was understood that the suggestions regarding the implementation process include STEM education should be integrated more into education programs and courses (Koçyiğit, 2019) and collaborative studies should be done with branch teachers (Gülhan, 2016). In addition, the findings of the doctoral theses examined include suggestions such as compulsory or elective courses on STEM should be given in education faculties (Türk, 2019) and in-service trainings and seminars should be given (Özdemir, 2018). In this context, suggestions for the studies that can be done in the doctoral theses examined were made regarding the application process and teacher education, and it can be stated that the study authors included suggestions in different dimensions.

Suggestions

As a result of the study, 30 doctoral theses in the field of STEM were examined and it was determined that the number of doctoral theses increased gradually starting from 2016. In this context, it is clear that doctoral theses in the field of STEM are important for the literature. However, the important thing is to produce original studies as required by doctoral theses instead of similar studies. In this context, although it is related to STEM, it can be suggested to carry out experimental studies with skills such as decision-making, system thinking, and entrepreneurship with little or no work. In addition, more generalizable results can be achieved by conducting meta-analysis studies for variables such as success and scientific process skills studied in STEM education.

When the doctoral theses are examined, it is seen that STEM applications are carried out in different subjects or fields. However, it is unclear whether they comply with STEM or whether they meet the requirements to be considered as STEM activities. For this purpose, it is thought that a rubric will be developed, it will be very appropriate for both the literature and the teachers who are its practitioners to examine the STEM activities developed and present them by combining the appropriate ones.

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