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# A review of researches on STEM in preservice teacher education

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**Abstract.** As the research on STEM education has begun to gain momentum in literature, the need for STEM education in the field of teacher training has been emphasized. Considering that STEM education plays an increasingly important role in teacher education both in our country and in the world, it is necessary to investigate the literature review that will guide these studies. According to the criteria determined in this study, 76 studies published between January 2001 and December 2018 were examined by using systematic review. These 76 studies are summarized under the categories of research, type of research, method research group, validity-reliability report, data collection tools, educational material, country of publication. The results of the research indicate that applied qualitative research methods are used mostly in preservice teacher education, the studies have increased significantly in the last three years, simple tools as education material are used mainly, and interview forms were preferred as the data collection tool. In the light of these findings, some suggestions are put forward to the teacher educators and researchers.

**Keywords:** STEM education, preservice teacher education, literature review

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## INTRODUCTION

STEM is an education approach which has been mentioned frequently in the fields of education, business and industry especially, in the last two decades but has no definite definition. Different institutions, organizations and researchers try to form the theoretical framework of STEM with concepts “interdisciplinary” and “integrated”. According to Hom (2014), STEM is an integrated educational approach that combines the disciplines of Science, Technology, Engineering and Mathematics with different topics in real life contexts simultaneously. Gonzalez and Kuenzi (2012) described STEM education as an interdisciplinary approach that covers the entire educational process from pre-school to higher education.

STEM education aims to enable students to look at the problems which they face from an interdisciplinary perspective and to gain knowledge and skills based on an integrated education approach (Şahin, Ayar, & Adıgüzel, 2014). According to Moore, Stohlmann, Wang, Tank and Roehrig (2013), STEM education is defined as the integration of the disciplines of Science, Technology, Engineering and Mathematics by structuring the content in the context of real life problems. In STEM education, integration takes place in the context of adapting these four areas in terms of content, or using one as a center and the others as context to teach the content of this centralized discipline.

The aim of STEM is to provide students with a learning environment to apply the knowledge and skills required by the 21st century (Bybee, 2013; Dugger, 2010; Sanders, 2009). From preschool to higher education, STEM education provides life-related interdisciplinary knowledge and skills and prepares students for knowledge-based economics (National Research Council-NRC, 2011). In the 21st century, students should be able to produce new knowledge and apply it to new situations and problems rather than to take existing knowledge readily (Wagner, 2008). There are many classifications related to 21st century skills (OECD, 2005; MoNE, 2011; World Economic Forum, 2015). However, in this study, the classification referred to as P21 was explained due to its widespread use. The general framework of the P21 is: Key issues-In addition

to the Mastery of "core subjects and 21st century themes" i) learning and innovation skills; ii) knowledge, media and technology skills; and iii) life and career skills (Partnership for 21st Century Learning, 2015) are classified as follows:

Learning and innovation skills

- Creativity and innovation
- Critical thinking and problem solving
- Communication and collaboration

Information, media and technology skills

- Information literacy
- Media literacy
- Information, Communications and Technology (ICT) literacy

Life and career skills

- Flexibility and adaptability,
- Inıtıatıve and self-directıon
- Social and cross-cultural interaction,
- Productivity and accountability,
- Leadership and responsibility skills

In order to have these skills for individuals, existing education systems should be reviewed and renewed according to these skills areas. STEM education facilitates the acquisition of these skills (Yıldırım, 2018, p. 11). STEM education is more progressive, student-centered and experimental than traditional teacher-centered education. STEM disciplines encourage the teacher to create a learning environment based on the constructivist approach that students learn by doing (Fioriello, 2010). Accordingly, it is very important how teachers will implement STEM education for the successful implementation of STEM education (Vescio, Ross & Adams, 2008). Pre-service teachers are trained in the knowledge, skills and beliefs necessary for the implementation of STEM education with the integrated teacher education program. Thus, teachers can improve students' innovation skills (Cuadra & Moreno, 2005; NRC, 2011).

Teachers are the most basic resource in STEM education system (Bybee, 2013). Educational institutions in many countries including institutions that are effective in Turkey (e.g., Council of Higher Education-CoHE, Ministry of National Education-MoNE), believe that providing broader access to STEM education requires effective teacher education programs (Çorlu, 2012). Standard teacher education programs focus on theory (Content or Pedagogical) rather than practice (Pedagogical content knowledge) (Çorlu & Çorlu, 2010; Kartal, 2011). Yıldırım (2017) emphasized STEM pedagogical content knowledge in providing quality and effective STEM educations for teachers. Yıldırım (2017) stated that STEM pedagogical content knowledge should focus on teachers' content knowledge, pedagogical knowledge, context knowledge, 21st century skill knowledge and integration knowledge. This is because these areas play an important role in providing STEM education effectively and professionally. Çorlu (2014) also proposed a model based on Shulman (1986), Hill, Schilling and Ball (2004) and the author's doctoral thesis (Çorlu, 2012). According to the model, STEM teacher

- has content knowledge at expert level.
- has pedagogical content knowledge at expert level.
- has an evolving knowledge in another field of STEM. The evolving knowledge gives to the teacher the ability to become an effective practitioner in both content and content education.
- developing knowledge specific to the field, profession by sharing with the stone. As a result of the sharings, professional learning communities are formed in schools and inter-groups cooperation is developed.

A new approach requires a new curriculum, professional development opportunities for existing teachers, and changes in teacher preparation programs from preschool to higher education (Wendt, Isbell, Fidan, & Pittman, 2015). It is not enough for teachers to have the

knowledge of teaching in their own fields to raise the manpower required for Turkey (Çorlu, Capraro and Capraro, 2014). A STEM teacher should have other knowledge in the STEM fields in addition to his/her field. This gives the teacher the competence to apply STEM in both field and field education (Çorlu, 2014). From this viewpoint, STEM education requires professional development and teacher education (Van Eck, Guy, Young & Winger, 2015).

If math and science teachers are raised to facilitate STEM education that encourages innovative and integrated thinking, innovations in STEM education can be successful in Turkey (Çorlu, 2012). Professional development opportunities should be provided with the courses that they will take in both in-service and education faculties. In order to increase the skills of teachers and pre service teachers towards STEM education, Hacettepe University and İstanbul Aydın University made their first attempts in this regard by opening STEM centers accessible to students and teachers (Akgündüz et al., 2016). On the other hand, Yıldırım (2018) structured the preparation process of teachers to STEM education according to the STEM teacher education model inspired by village institutions in the STEM education report. When the purposes of establishment of village institutes were evaluated in terms of STEM education, it was seen that they involved similar processes. In order to equip individuals in different fields in village institutes, the teachers who will raise them should have interdisciplinary knowledge. In addition, knowledge is related to daily life, in other words, theoretical knowledge is applicable in daily life. STEM teacher institutes education model was proposed to raise a generation of teachers studying in an interdisciplinary, having comprehensive konowledge about the industry 4.0, having a good level of algorithms and software, and having engineering knowledge and skills. In line with these objectives primarily, teacher is educated and then the experienced teachers are mentors to the other teachers. In this way, the model enables the application of knowledge in a learning process in which the students are active. Together with the model, students are in a position to produce technology in an educational approach related to industry and trade. In addition, students acquire knowledge and skills related to artistic activities as well as STEM disciplines (Yıldırım, 2018). As a result, the report prepared by Yıldırım (2018) is very important in that it includes the preparation process of STEM teachers.

When the researches about STEM education in national and international literature are examined, the need for STEM education in the field of pre-service teacher education has started to be emphasized. Considering that STEM education is an increasingly important approach in teacher education both in our country and in the world, the necessity of a review to guide the studies comes to the fore. Therefore, this study aimed to (i) determine in what contexts STEM-oriented studies were conducted with preservice teachers in the national and international literature, and (ii) to evaluate the findings of the STEM studies integrated with the national and international literature, and to provide recommendations for future researches and practices.

## METHODS

In this study, Systematic literature analysis research method was used to examine STEM studies related to preservice teacher education. Systematic literature analysis in educational researches is conducted in order to reach the results that lead to future research by revealing important interactions and connections in the literature (Minner, Levy & Century, 2010). In this study, a three-step method was followed: the identification of the review method and the selection criteria, (ii) the review process, and (iii) the analysis process (Karaçam, 2013). The process steps performed in each step of the research are explained in detail below.

### 2.1. Reviewing strategy and selection process

Firstly, article selection criteria and keywords were determined. In the selection of articles; (i) published between 2001 and 2018, (ii) followed qualitative and/or quantitative scientific research methodology, (iii) published in peer-reviewed journals, and (v) focused on STEM education for preservice teachers. According to Christenson (2011) Judith A. Ramaley,

director of the National Science Foundation's (NSF) education and human resources department in that period, proposed shortening these disciplines (Science, Technology, Engineering And Mathematics) as STEM. For this reason, the studies conducted between January 2001 and December 2018 were included in the review. In the research process, qualitative, quantitative and mixed method researches were taken into consideration in order to examine in depth the STEM-oriented studies for preservice teachers. Attention was paid to the fact that the researches were published in refereed journals. In addition, the studies should be carried out within the framework of STEM education for preservice teachers. In line with these criterias, key words for STEM studies conducted with preservice teachers in literature were determined and searches were conducted in Turkish and English languages. Keywords used in review:

STEM and Preservice Teachers

STEM and Pre-Service Teachers

STEM and Teacher Candidates

STEM and Prospective Teachers

### 2.2. Review Process

With the determined keywords, Eric, Ebsco, Science Direct, Scopus, Web of Science, Taylor & Francis, Springer, Ulakbim, and finally, Google Scholar search engine were searched. The titles and abstracts of the articles were examined in the determined databases and three reviewing were performed at regular periods according to the search strategy and keywords. 131 articles were reached during the reviewing process. However, other academic publications such as theoretical studies, conference proceedings, dissertations and books were excluded from the scope of the research. When the full texts of the studies were examined, the studies which evaluated university students in STEM fields rather than STEM education as an approach were excluded from the research. STEM activities developed by preservice teachers were also excluded because they did not meet the criteria of research type (implemantation or survey). According to the search strategy and keywords that reviewed in the determined databases, 86 studies were entered in accordance with the article analysis table. At this stage, expert opinion was consulted. Considering the expert opinion, 10 articles that included any data collection process for preservice teachers were excluded from the scope of the research.

### 2.3 Analysis process

The contents of the articles determined by the researchers were examined individually and summarized in the article analysis table under the following categories: study, study type, method, subjects, reliability-validity report, data sources, Education material, method and technique used, country context. In addition, a separate analysis table was developed for scale development/adaptation studies. In this table, the categories were determined as: study, scale development/implemantation, scale adaptation/implementation, adapted or developed scale and subjects. Each article was examined in detail according to these categories and after the process of entering the spreadsheet (excel) table, STEM education studies and the results of the studies were examined in detail according to similarities and differences.

## FINDINGS

### 3.1 STEM education publication trends in preservice teacher education

In this section, a graph that shows the distribution by years of the studies determined in preservice teacher education is obtained and comments were made according to the graph.

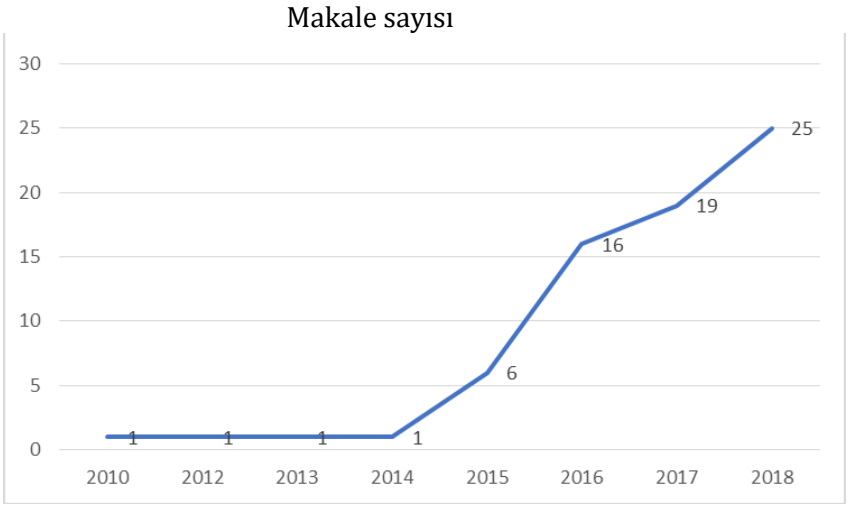


**FIGURE 1.** *Publication trends between 2001-2018*

In this study, the articles published between 2001-2018 were examined. When the articles were analyzed by years, it was found that the studies started in 2010 and increased according to years. According to figure 1, the majority of the studies were conducted in the last three years. Distribution of study group by branches: science teacher (n: 19), primary teacher (n: 7), preschool teacher (n: 3), mathematics teacher (n: 2), chemistry teacher (n: 2) , physics teacher (n: 1), mixed study group (n: 41) consisted of preservice teachers from different subjects. It was found that STEM studies conducted with preservice teachers with a mixed sample group mostly. Following mixed groups, it was possible to list the most studied areas as science, primary and preschool education respectively.

6 studies did not reveal any validity and reliability analysis in 76 research reports analyzed. Interview form, observation form, scale, questionnaire, reflection paper, lesson plans, project tasks were identified as data collection tools.

In the scope of the research, the educational materials used in implemantation studies were simple tools, programming-robotics, instructional video, animation-simulation, 3D design programs, mobile application, digital tools such as 3D printers, game programs (minecraft), coding and others. However, it was found that simple tools were mostly used in implementation studies. Simple tools was followed by STEM activities with robotic programming. Some research reports did not reveal any information about the materials used for the activities and are given in the appendix. The study (n = 76), 55% (n = 41) in Turkey, 31% (n = 22) in the United States, 14% (n = 13) in the context of the other countries was conducted.

### 3.2 Method and design in STEM studies

The purpose of the studies was classified as survey or implementation. Approximately 73% of the articles were identified as implementaton that focused on the application on the STEM education programs, projects, courses and so on, 20% of them were identified as survey that described the current situation (perception, attitude, opinion, etc.). Scale development and adaptation studies constituted 7% of the current studies. Various method and designs were used in the studies examined within the scope of this research. Research methods used in the articles are qualitative (screening, case study, action research, phenomenology, etc.), quantitative (scale adaptation and development, experimental, survey) and mixed-patterned studies were grouped under three groups. 41 studies were conducted by using qualitative methods in the 76 studies conducted in the field of STEM. Data sources included interview forms and reflection writings were used mostly as data collection tools, respectively. In addition, 19 studies were conducted using quantitative methods and only 5 of these studies were scale development and adaptation studies. Scales were used as the data source in quantitative studies. The number of studies used

mixed methods was determined as 14. In addition, Educational design research method was used to create an online learning module in only a research.

### 3.3 Scale development and adaptation studies

Within the scope of this research, 6 scales were developed and adapted. 5 scales have been conducted in Turkey: The validity and reliability of the Turkish version of the "Integrated STEM (Science, Technology, Engineering and Math) Teaching Intention Scale" developed by Lin and Williams (2015) (Hacıömeroğlu & Bulut, 2016); "STEM awareness scale" which was developed by Buyruk and Korkmaz (2016); The validity and reliability of the Turkish version of the "STEM semantics survey" which was developed by Knezek and Christensen (2008) and validated by TylerWood, Knezek and Christensen (2010), was developed by Friday Institute for Educational Innovation (2012). The validity and reliability of the Turkish version of the "Teacher efficacy and attitudes toward STEM survey-science teachers" (Yıldırım, 2018). Integrative STEM Teaching Intention Questionnaire) was developed by Lin and Williams (2015). As mentioned before, scale development and adaptation studies were limited compared to other studies.

### 3.4 Theoretical structure of STEM researches in preservice teacher education

When the articles that was reviewed within the scope of the research were examined in terms of the theoretical foundations of STEM education, the results were obtained as follows:

**Table 1.** *Research and theoretical foundations of researches*

| Research | Theoretical foundations of researches |
|---|---|
| Geiger, Mulligan, Date-Huxtable, Ahlip, Jones, May, Rylands and Wright (2018) | Mathematical modelling (Blum & Niss, 1991); 21st Numeracy Model (Goos et. al., 2014) and 5Es instructional model (Bybee, 2009) |
| Kertil and Gürel (2016) | Mathematical modelling, Project based learning, Integrative STEM education |
| French and Burrows (2018); Schmidt and Fulton (2016) | Inquiry based learning |
| Hacıoğlu, Yamak and Kavak (2017); Bozkurt Altan, Yamak and Buluş Kırıkkaya (2016) | Engineering design process (Bozkurt, 2014; Wendell et. al., 2010; Hynes et. al., 2011) |
| Radloff and Guzey (2016) | Constructivism |
| Gökbayrak and Karışan (2017) | Inquiry-based learning |
| Aslan-Tutak, Akaygün and Tezsezen (2017) | Collaborative module |

| Research | Theoretical foundations of researches |
|---|---|
| Tarkın-Çelikkıran and Aydın-Günbatar (2017); Aydin-Gunbatar, Tarkin-Celikkiran, Kutucu and Ekiz-Kiran (2018) | Engineering Design Process Model (Wheeler, 2014) |
| Lin and Williams (2017) | Dewey's learning experience theory (1929) |
| Marshall and Harron (2018) | Situated cognition and Problem based learning |
| Delen and Uzun, (2018) | Project based learning and Mathematical modelling |
| Novak and Wisdom (2018); Awad and Barak (2018); Siew, Amir and Chong (2015) | Project based learning |
| Ryu, Mentzer and Knobloch (2018) | Integrative STEM education, Situated learning and cognition |
| Smyrnova-Trybulska, Morze, Kommers, Zuziak and Gladun (2017); Nowikowski (2016) | Interdisciplinary activity |
| Adams, Miller<br>Saul and Pegg (2014) | Place based STEM learning activities |
| Yıldırım (2018) | Context based learning |

In the study conducted by Geiger, Mulligan, Date - Huxtable, Ahlip, Jones, May, Rylands and Wright (2018), the process of developing online learning modules on mathematical modeling was based on the theoretical foundations mentioned in the Table 1. Kertil and Gürel (2016) supported integrated STEM education practices with project-based learning method and mathematical modeling activities in terms of context and content.

French and Burrows (2018) prepared inquiry-based STEM lesson plan scenarios. Schmidt and Fulton (2016) transformed an inquiry based science unit into inquiry based STEM units. Gökbayrak and Karışan (2017) prepared laboratory practices based on STEM based research-inquiry approach.

In some studies, STEM education was conducted according to engineering design based science education structured according to Hynes et al. (2011) (Hacıoğlu, Yamak & Kavak, 2017; Bozkurt Altan, Yamak & Buluş Kırıkkaya, 2016). Different STEM researches structured according to the Wheeler's (2014) engineering design process model were carried out (Tarkin-Çelikkıran & Aydın-Günbatar, 2017; Aydın-Günbatar, Tarkın-Çelikkıran, Kutucu & Ekiz-Kıran, 2018). Aslan-Tutak, Akaygün and Tezsezen (2017) developed a cooperative STEM education module. The word "cooperation" emphasizes the meaning of cooperation between fields (interdisciplinary). Lin and Williams (2017) designed a two stage hands on technology learning activity based on Dewey's (1929) learning experience theory. Marshall and Harron (2018) structured STEM education within the framework of situated cognition and problem based learning theories and based it on the concept of context. In order to conceptualize STEM education, Delen and Uzun (2018) used mathematical modeling as a bridge within the framework of Project based STEM activities. Novak and Wisdom (2018) prepared 3D printer applications according to project based learning. Awad and Barak (2018) prepared STEM activities according to Project based learning. Ryu, Mentzer and Knobloch (2018) have based the theoretical foundations of STEM education on integrated STEM education and thus explained the prospective learning experiences of prospective teachers. There are other studies that was based on theoretical foundations to integrated STEM education (e.g. Radloff & Guzey, 2017). In the study conducted by Yıldırım (2018), STEM practices were prepared according to context based learning.

### 3.5 Results of STEM researches in preservice teacher education

Under this title, the common results of STEM education activities done with preservice teachers were summarized and presented. 20% of the determined STEM researches were classified as survey researches that determine preservice teachers' perceptions, attitudes, opinions and so on. Various results were obtained depending on the variables of the research in the context of preservice teacher education.

In the study conducted by Buyruk and Korkmaz (2016), it was determined that STEM awareness of preservice teachers was high. On the other hand, in the study conducted by Bakırcı and Karışan (2018), STEM awareness of preservice primary and science teachers was found to be higher than mathematics preservice teachers. However, in both studies, it was found that gender variable had no effect on STEM awareness. Moreover, Deveci (2018) determined that STEM awareness of pre-service teachers significantly predicted entrepreneurial characteristics.

There are studies examined the preservice teachers' views on STEM education (e.g. Çalışıcı & Özçakır Sümen, 2018; Kırılmazkaya, 2017). It was concluded that STEM education is generally beneficial, important and necessary. Radloff and Güzey (2016) investigated how pre-service teachers conceptualize STEM education textually and visually. Madden, Beyers and O'Brien (2016) investigated the importance and reasons of STEM education at basic levels according to the preservice teachers. All of the preservice teachers stated that STEM is important.

According to the research conducted by Pimthong and Williams (2018), the preservice teachers explained STEM as science, technology, engineering and mathematics but could not

explain how the four disciplines are integrated. But they were able to explain the results of integration. Similarly, in the study conducted by Hacıoğlu, Yamak and Kavak (2016), it was found that ”technology, engineering and mathematics” disciplines were not associated with science discipline. In addition, It was concluded that they could not establish the relationship between science education and STEM disciplines, science and science education concepts. On the other hand, Özçakır, Sümen and Çalışıcı (2016) found that preservice teachers were able to associate science curriculum gains with engineering field.

Türk, Kalaycı and Yamak (2018) conducted a need analysis for the STEM education program in the field of science education in the faculties of education. The findings of the research reveal that there is no study to integrate different fields into teacher education programs, there is no course related to STEM education integrated into the curriculum. Consequently preservice teachers should acquire the knowledge and skills that is necessary to apply this approach. Professional education career is not available in the curriculum. In addition, it is concluded that most of the teachers believe in teacher collaboration and teachers mostly associate their courses with mathematics and information technologies. Likewise, the main reason behind teachers' inability to teach with an interdisciplinary approach was determined as teacher-related reasons. Regarding pre-service education, the Ministry of National Education and faculties of education should work in cooperation, determine teacher competencies, and try to develop undergraduate curricula so that preservice teachers can acquire these competencies. It was stated that the implementation of pre-service education period before the in-service education of the teachers will play a very important role in order to obtain the results expected from the approach.

Preparing a teacher education program, activity, etc. in the framework of STEM education and examining their effects on preservice teachers were classified as implementation studies. The researches classified in this context aimed to provide STEM competency to preservice teachers in accordance with the program, activity and so on. For example, the study aimed to provide preservice teachers with orientation knowledge to careers in accordance with the their students’ interests and needs (Pinnell, Rowly, Preiss, Franco, Blust & Beach, 2013). (Pinnell, Rowly, Preiss, Franco, Blust & Beach, 2013).

STEM practices enriched with robotics, coding and 3D design technologies and integrated science, mathematics and engineering disciplines are available. In the study conducted by Novak and Wisdom (2018), it was observed that STEM practices included 3D printer technologies decreased the participants' anxiety about science teaching and increased the effectiveness of science teaching and science interest. In addition, the project reflections of preservice teachers and analysis of boat designs provided insight into collaborative 3D modeling design experiences. Jones, Smith and Cohen (2017) found that preservice teachers had positive attitudes towards using maker activities in their future teaching lives. They also stated that in teacher preparation programs, a process in which maker tools and activities were compatible with teaching strategies (problem based learning, inquiry based learning and hands on learning activities) encouraged them. It has been concluded that there is a positive effect on the variables “self-efficacy in teaching with robotics, science conceptual and computational thinking skills and so on” (determined within the scope of the research) in researches involved robotic practices (e.g., Jaipal-Jamani & Angeli, 2017; Kim, Kim, Yuan, Hill, Doshi & Thai, 2015).

Studies indicated that game-based activities lead to positive developments on preservice teachers (McColgan, Colesante and Andrade, 2018); preservice teachers’ content knowledge has increased with video-based games (Van Eck, Guy, Young, Winger & Brewster, 2015).

In a group of researches based on engineering design based STEM education (e.g., Hacıoğlu, Yamak & Kavak, 2017; Bozkurt Altan et. al., 2016), preservice teachers have positive opinions about engineering design based STEM education. For example, preservice teachers

think that engineering design process ensures learning by doing, big design task ensures motivation, permanent learning, and based on inquiry method.

According to the research results, that STEM education practices have positive effects on preservice teachers' views on the nature of science (Krell, Koska, Penning & Krüger, 2015); attitudes towards renewable energy sources (Yıldırım & Selvi, 2016), STEM awareness (Gökbayrak & Karışan, 2017), the preservice teachers' sensitivities and behaviors towards the environment, their dependence of nature and their attitudes towards technology (Yıldırım, 2018), mathematics literacy self-efficacy and technological pedagogical content knowledge but negative effect on mathematical thinking (Yıldırım & Sidekli, 2018). Tomšik and Čerešník (2017) concluded that the teaching motivation of preservice teachers received and not received STEM education was in favor of those receiving STEM education. Nowikowski (2016) conducted a study of pre-service teachers' experiences with STEM modules in mathematics and science teaching. As a result of this study, pre-service teachers' self-efficacy towards STEM teaching improved and definitions of STEM teaching increased.

In the studies conducted to determine the effect of STEM practices on the opinions of preservice teachers about STEM education, it was found that preservice teachers generally had positive thoughts about STEM education approach (e.g., Uğraş & Genç, 2018; Erdoğan & Çiftçi, 2017). In the studies of Aslan-Tutak, Akaygün and Tezsezen (2017), the definitions of preservice teachers changed in accordance with integrated structure of STEM education. In addition, preservice teachers emphasized participating in seminars and practices for STEM teacher education, observing project examples and sharing their experiences. Similarly, results indicate that pre-service teachers need education to ensure STEM integration (Lin & Williams, 2017; Delen & Uzun, 2018). Schmidt and Fulton (2016) conclude that preservice teachers need inquiry based learning and education about technology integration in the process of transforming an inquiry-based unit into a STEM unit.

After STEM education practices, studies were conducted to investigate the preservice teachers' intention towards STEM teaching (Lin & Williams, 2016; Adams, Miller, Saul & Pegg, 2014). Adams, Miller Saul, and Pegg (2014) implicated that place-based STEM teaching have a positive effect on preservice teachers' intention to design and implement STEM activities. Çetin and Balta (2017) revealed that preservice teachers (especially women) were more willing to use STEM materials in their future teaching lives. According to the participants, STEM materials facilitate learning, increase persistence and self-esteem. However, preservice teachers who believe that it is difficult to prepare STEM materials stated that it took too much time and was not suitable for the students' level.

It has been determined that STEM education has an effect on the development of pre-service teachers' content knowledge (Aydın-Günbatar, Tarkın-Çelikkıran, Kutucu & Ekiz Kıran, 2018; Tarkın Çelikkıran & Aydın Günbatar, 2017). For example; In the study conducted by Tarkın-Çelikkıran and Aydın-Günbatar (2017), preservice teachers stated that STEM education trainings made important contributions to the disciplinary view and chemistry content knowledge in respect to recall/ reinforce what was learned. They mentioned the steps of researching for design and as a result of this, designing are as the most instructive points. Finally, preservice teachers were forced to decide on the materials to be used, how to design the product and to research/obtain the necessary information.

In the literature, there is only a research conducted by Geiger et al. (2018). The aim of the research was to determine the processes and evaluation used to develop an online learning module on mathematical modeling. It was concluded that the development process of the module was positive but the participation of other stakeholders than preservice teachers was necessary in the development process.

## DISCUSSION AND CONCLUSION

The increasing number of STEM-focused studies in our country and international literature in recent years shows the importance given by politicians, educational researchers and teacher educators. For this reason, STEM researches which directs important studies not only in our country but also international literature should be discussed according to systematic literature analysis methodology in preservice teacher education. In this section, the findings obtained from the literature were listed and recommendations were made to researchers, teacher educators and educational politicians in the light of these findings.

STEM studies conducted with preservice teachers have increased significantly in the last three years. Although researches related to the engineering design process in Turkey made in previous years (Marulcu & Sungur, 2012), for the first time STEM studies in teacher education in 2015 (Yıldırım & Altun) were seen. Thus, approximately half of the researches that was determined by researchers was carried out in the context of Turkey in the last 3 years. Most of the related researches are implemantation type and include theoretical knowledge and activities about STEM.

Approximately more than half of the studies were conducted in groups contained mixed samples. The group consisting of mixed samples was followed by studies with preservice science teachers and it was relatively more than the other preservice teacher groups. In STEM education, there is more need for implemantation research with mixed sample groups. As a matter of fact, STEM education is an interdisciplinary process and teacher trainings require preservice teachers from different branches to work together.

Few of the studies analyzed (n: 6) did not include validity and reliability analysis in the research reports. In addition, there were 9 studies which included pilot application of the measurement tool in the validity and reliability analysis (Aydın-Günbatar et. al.,, 2018; Lin & Williams, 2015; Yıldırım & Altun, 2015; Yıldırım & Sidekli 2018). Türk, Kalaycı & Yamak, 2018; Marshall & Harron, 2018; Buyruk & Korkmaz, 2016; Bozkurt Altan, et. al., 2016; Yıldırım, 2017).

In the researches, interview forms were mostly used as data collection tools. Questionnaires consisted of scales and open-ended questions became the most preferred data collection tools after interview forms. However, when literature was examined, the limited number of scales related to STEM education (Lin & Williams, 2015; Buyruk & Korkmaz, 2016; Knezek & Christensen, 2008; Yaman, Özdemir, Akar & Vural, 2018; Yıldırım, 2018) encouraged researchers to use interview forms. For studies involving a larger studying group, STEM-focused, valid and reliable measurement tools are needed.

In the researches of the implementation type, the educational tools required by the hands on-minds on method were used as educational materials. Especially basic materials were used mostly but, technology-oriented robotics-coding, animation-simulation, etc. of educational materials were preferred a few of researches.

More than half of the surveys were conducted using qualitative research methods and implemantation type. After qualitative research, quantitative and then mixed research methods were preferred respectively. In only one study, Educational Design Research (ETA) method was used. Design research enables the design and development of interventions such as programs, learning-teaching strategies, materials, products and systems for complex educational problems, as well as information about the characteristics, design and development processes of these applications (Plomp, 2013, p. 15). It may be recommended to use ETA more frequently in STEM researches as a resource for teacher preparation programs and MoNE to develop STEM activities and to describe the extention of theoretical content in detail.

Twenty-one of the researches were structured according to models, approaches, methods and techniques such as engineering design process, inquiry based learning, mathematical modeling, project and problem based learning. STEM education has been receiving increasing demand in recent years. Therefore, specifying the theoretical foundations of the

researches with justifications will enable STEM education to be established on solid foundations. However, most studies only explain STEM trainings and its effects.

The results of the surveys showed that preservice teachers need training to ensure the integration of STEM disciplines (Hacıoğlu, Yamak & Kavak, 2016; Pimthong & Williams 2018). They concluded that preservice teachers had positive opinions about STEM education (Çalışıcı & Özçakır Sümen, 2018; Kırılmazkaya, 2017). In the implemantation researches, it was concluded that the dependent variable had a positive effect on the independent variable.

Finally, it is an important gap in the literature. There is no research concerning about STEM pedagogical content knowledge of the preservice teachers'. At this point, the general framework of STEM pedagogical content knowledge was determined by Yıldırım (2017). In addition, Çorlu (2014) proposed a model called "integrated teaching knowledge" to the researchers studying in teacher education. However, it is suggested that these theoretical researches should be transformed into implementation or survey research with preservice teachers and the results of the variables that researchers want to investigate should be shared. On the other hand, taking into account the results of the researches about pedagogical and content knowledge related to STEM education is very important in terms of its reflection into preservice teacher education programs. In fact, instead of inservice education, pre-service education of teachers plays an important role in achieving the expected results from the approach (Türk et. al., 2018).

Although STEM was first introduced in 2001 by the American National Science Foundation (NSF) manager Judith A. Ramaley, it has become an increasingly popular educational approach both in our country and in the world. In our country, STEM-oriented studies in teacher education research and applications are increasing. The findings, discussions, and recommendations of this systematic literature analysis aimed to shed light on the future STEM studies both in our country and international literature. In the context of our country, STEM-oriented studies in teacher education should be made widespread. Teacher education programs should be developed or existing programs should be improved in order to enable pre-service teachers to apply STEM education in their professional lives.

**Appendix 1.** Systematic analysis of articles

| Study | Type | Method | Subjects | Reliability, validity report | Data sources | Education material, method and technique used | Country context |
|---|---|---|---|---|---|---|---|
| Adams, Miller Saul & Pegg (2014) | Implementation | Qualitative | Preservice primary teachers | * | Interview form, reflection paper, observation, lesson plans and students' studies | Hands on | Usa |
| Akaygün & Aslantutak (2016) | Implementation | Qualitative | Preservice Chemistry and mathematics teachers | * | Poster | ----- | Turkey |
| Aslan-Tutak, Akaygün & Tezsezen (2017) | Implementation | Quantitative | Preservice chemistry and mathematics teachers | * | Questionnaire included open ended questions | Modelling with QR codes<br>Hands on | Turkey |
| Awad & Barak (2018) | Implementation | Mix methods | Preservice teachers | * | Final examination, Retention exam, motivation questionnaire, Final projects, Interview, Observation | ICT (Information and Communication Technologies) and hands on | Israel |
| Aydın-Günbatar, Tarkın-Çelikkıran, Kutucu & Ekiz-Kıran (2018) | Implementation | Mix methods | Preservice chemistry teachers | * | Chemistry tests, Interview, reflection paper | Hands on | Turkey |
| Bakırcı & Karışan (2017) | Survey | Quantitative | Preservice primary, mathematics and science teachers | * | Scale | | Turkey |
| Berlin & White (2012) | Implementation | Quantitative | Preservice teachers | * | Scale | ----- | Usa |
| Blackley, Sheffield, Maynard, Koul & | Implementation | Qualitative | Preservice tachers, engineering | * | Focus group interview form, Reflection form | Hands on | Australia |

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|---|---|---|---|---|---|---|---|
| Walker (2017) | | | students, preschool students | | | | |

| Study | Type | Method | Subjects | Reliability, validity report | Data sources | Education material, method and technique used | Country context |
|---|---|---|---|---|---|---|---|
| Bozkurt Altan, Öztürk & Yenilmez Türkoğlu (2018) | Implementation | Qualitative | Preservice science teachers | * | Field notes and interview | ---- | Turkey |
| Bozkurt Altan, Yamak & Buluş Kırıkkaya (2016) | Implementation | Qualitative-durum | Preservice science teachers | * | Interview | Hands on | Turkey |
| Buyruk & Korkmaz (2016) | Survey | Quantitative | Preservice Mathematics and Information technologies and science teachers | * | Scale | | Turkey |
| Carrier, Whitehead, Walkowiak, Luginbuhl & Thomson (2017) | Implementation | Qualitative | Preservice teachers | * | Interview, Observation | ----- | Usa |
| Çalışıcı & Özçakır Sümen (2018) | Survey | Qualitative | Preservice primary teachers | * | Metaphor form | | Turkey |
| Çetin & Balta (2017) | Implementation | Qualitative | Preservice science teachers | | Interview | Hands on | Turkey |
| Çetin & Kahyaoğlu (2018) | Implementation | Mix methods | Preservice science teachers | * | Scale, Interview | Robotic-coding | Turkey |
| Çınar, Pırasa & Sadoğlu (2016) | Implementation | Qualitative | Preservice elementary department, physics and | * | Questionnaire including open ended questions | Hands on, robotic | Turkey |

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|---|---|---|---|---|---|---|---|
| | | | mathematics teachers | | | | |
| Çınar, Pırasa, Uzun & Erenler (2016) | Implementation | Qualitative - durum | Preservice science teachers | * | Word association test, Questionnaire including open ended questions | ------ | Turkey |

| **Study** | **Type** | **Method** | **Subjects** | **Reliability, validity report** | **Data sources** | **Education material, method and technique used** | **Country context** |
|---|---|---|---|---|---|---|---|
| Dani, Hartman & Helfrich (2018) | Implementation | Qualitative | Preservice elementary teachers | | Document, Observation, reflection paper, field notes, final task | Hands on | Usa |
| Delen & Uzun, (2018) | Implementation | Qualitative-durum | Preservice mathematics teachers | * | Interview, lesson plans | 3D printer-hands on | Turkey |
| Deveci (2018) | Survey | Quantitative | Preservice science teachers | * | Scale | | Turkey |
| Ercan, Bozkurt Altan, Taştan & Dağ (2016) | Implementation | Qualitative | Preservice science teachers | * | Written science texts of teacher candidates | Geographic information system (digital) | Turkey |
| Erdoğan & Çiftçi (2017) | Implementation | Qualitative-durum | Preservice science teachers | * | Interview | Hands on | Turkey |
| French & Burrows (2018) | Implementation | Qualitative | Preservice teachers | * | Scenario and questions related scenario | Robotic | Usa |
| Geiger, Mulligan, Date-Huxtable, Ahlip, Jones, May Rylands & Wright (2018) | Implementation | Qualitative-tasarım | Experts form STEM disciplines and Preservice teachers | * | Interview | Online learning module | Australia |
| Gökbayrak & Karışan (2017) | Implementation | Quantitative | Preservice science teachers | * | Scale | ----- | Turkey |

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|---|---|---|---|---|---|---|---|
| Greene-Clemons (2016) | Implementation | Mix methods | Preservice teachers | | Open and closed ended questions | Technological model | Usa |
| Hacıoğlu, Yamak & Kavak (2017) | Implementation | Qualitative-Eylem araştırması | Preservice science teachers | * | Interview | Hands on | Turkey |
| Hacıoğlu, Yamak & Kavak (2016) | Survey | Qualitative | Preservice science teachers | * | Word association test, Interview | | Turkey |
| **Study** | **Type** | **Method** | **Subjects** | **Reliability, validity report** | **Data sources** | **Education material, method and technique used** | **Country context** |
| Jaipal-Jamani & Angeli (2017) | Implementation | Quantitative | Preservice primary teachers | * | Questionnaire, scale, test | Robotic | Usa |
| Jones, Smith & Cohen (2017) | Implementation | Qualitative | Preservice teachers | * | Interview | Digital tools (3D printer, computer programming, etc.), hands on | Usa |
| Kırılmazkaya (2017) | Survey | Quantitative | Preservice primary teachers | * | Scale | | Turkey |
| Kim, Kim, Yuan, Hill, Doshi & Thai (2015) | Implementation | Mix methods | Preservice primary teachers | * | Scale, observation, lesson plan, interview, knowledge assessment form | Robotic | Usa |
| Kim, Yuan, Vasconcelos, Shin & Hill (2018) | Implementation | Qualitative | Preservice preschool teachers | * | Video recording, computer screen recordings, Interview | Coding and programming | Usa |
| King, Lyons, Dawes, Doyle & O'Loughlin (2018) | Implementation | Qualitative | Teachers, Heads of department, Industry partners and Preservice teachers | | Interview | Hands on | Australia |

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|---|---|---|---|---|---|---|---|
| Kocakaya & Ensari (2018) | Implementation | Qualitative | Preservice physics teachers | | Interview | Hands on | Turkey |
| Koyunlu Ünlü & Dere (2018) | Implementation | Qualitative | Preservice preschool teachers | * | Activity and activity reports | Hands on | Turkey |
| Krell, Koska, Penning & Krüger (2015) | Implementation | Quantitative | Preservice teachers | * | Questionnaire | Hands on | Germany |
| Lin & Williams (2017) | Implementation | Qualitative | Preservice science teachers | * | Portfolio and interview | Hands on | Taiwan |

| **Study** | **Type** | **Method** | **Subjects** | **Reliability, validity report** | **Data sources** | **Education material, method and technique used** | **Country context** |
|---|---|---|---|---|---|---|---|
| Madden, Beyers & O'Brien (2016) | Survey | Qualitative | Teachers and preservice teachers | * | Questionnaire | | Turkey |
| Marshall & Harron (2018) | Implementation | Qualitative | Preservice teachers | * | Rubric | Digital tools (aurdino)<br>Production tools (board etc.) | Usa |
| McColgan, Colesante & Andrade (2018) | Implementation | Mix methods | Preservice teachers | * | Questionnaire and reflection writings | Game based learning (minecraft) | Usa |
| McDonald (2017) | Implementation | Qualitative | Preservice science teachers | | Interview | ----- | Australia |
| Novak & Wisdom (2018) | Implementation | Mix methods | Preservice primary teachers | * | Scales, reflection writings, class discussion and 3D designs | 3D printer | Usa |
| Nowikowski (2016) | Implementation | Qualitative-durum | Preservice teachers | *(geçerlik var) | Reflection diaries, university programme, observation | Hands on | Usa |
| Pimthong & Williams (2018) | Survey | Mix methods | Preservice primary teachers | | Questionnaire and Interview | | Thailand |

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|---|---|---|---|---|---|---|---|
| Pinnell, Rowly, Preiss, Franco Blust & Beach (2013) | Implementation | Mix methods | Teachers and Preservice teachers | * | Reflection paper, scale | Hands on | Usa |
| Radloff & Guzey (2017) | Implementation | Qualitative | Preservice teachers | | Interview, reflection paper, lesson plan | Watching videos | Usa |
| Radloff & Guzey (2016) | Survey | Qualitative | Preservice teachers | * | Questionnaire | | Usa |
| Ryu, Mentzer & Knobloch (2018) | Implementation | Qualitative | Secondary preservice teachers | * | Interview, lesson plans, refleciton wrtings, final exam | Hands on | Usa |
| Schmidt & Fulton (2016) | Implementation | Qualitative - durum | Preservice primary teachers | * | Field notes, open ended questions, Alan notları, açık uçlu soru, assessments weekly | Instructional video, multimedia (mobile application) | Usa |
| **Study** | **Type** | **Method** | **Subjects** | **Reliability, validity report** | **Data sources** | **Education material, method and technique used** | **Country context** |
| Siew, Amir & Chong (2015) | Implementation | Mix methods | Teachers and Preservice teachers | | Questionnaire, Interview, open ended questions, class discussions | Hands on | Malaysia |
| Smyrnova-Trybulska, Morze, Kommers, Zuziak & Gladun (2017) | Implementation | Qualitative | Preservice primary teachers and teachers | * | Questionnaire | Robotic | Poland and Ukraine |
| Özçakır Sümen & Çalışıcı (2016) | Implementation | Qualitative-durum | Preservice primary teachers | * | Mind map and interview | Simulations<br>Google Sketchup (3D modelling)<br>Designing poster, drawing | Turkey |
| Özçakır Sümen & Çalışıcı (2016) | Survey | Qualitative | Preservice teachers | * | Questionnaire, Interview | | Turkey |
| Tarkın-Çelikkıran | Implementation | Qualitative | Preservice | * | Reflection wrtings | Hands on | Turkey |

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|---|---|---|---|---|---|---|---|
| & Aydın-Günbatar (2017) | | | chemistry teachers | | | | |
| Tekerek & Tekerek (2018) | Implementation | Qualitative | Preservice teachers about engineering | * | Observation, open ended questions and Interview | ------ | Turkey |
| Tomšik & Čerešník (2017) | Survey | Quantitative | Preservice teachers | | Questionnaire | | Slovakia |
| Türk, Kalaycı & Yamak (2018) | Survey | Qualitative | Academicians from department of Science, Mathematics, Computer and Instructional Technologies, Science teachers, Preservice science teachers | * | Interview | | Turkey |
| **Study** | **Type** | **Method** | **Subjects** | **Reliability, validity report** | **Data sources** | **Education material, method and technique used** | **Country context** |
| Tyler-Wood, Knezek & Christensen (2010) | Survey | Quantitative | Combined group including preservice teachers | * | Questionnaire | | Usa |
| Uğraş & Genç (2018) | Implementation | Mix methods | Preservice preschool teachers | * | Interview and scale | LEGO set | Turkey |
| Van Eck, Guy, Young, Winger & Brewster (2015) | Implementation | Mix methods | Preservice primary teachers | * | Scales, questionnaire, reflection wrtings, achievement test | Video game | Usa |
| Wendt, Isbell, Fidan & Pittman (2015) | Implementation | Qualitative | Preservice elementary teachers | | Interview | Hands on | Usa |

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|---|---|---|---|---|---|---|---|
| Yıldırım Şahin & Tabaru (2017) | Implementation | Quantitative | Preservice science teachers | * | Scale | | Turkey |
| Yıldırım (2017) | Survey | Qualitative | Preservice science teachers | * | Interview | | Turkey |
| Yıldırım (2018) | Implementation | Quantitative | Preservice science teachers | * | Scales | Hands on | Turkey |
| Yıldırım & Altun (2015) | Implementation | Quantitative | Preservice science teachers | * | Learning level test | Fishertechnik lego and pieces(robotic) | Turkey |
| Yıldırım & Selvi (2016) | Implementation | Mix methods | Preservice science teachers | * | Scales and Interview | ------ | Turkey |
| Yıldırım & Sidekli (2018) | Implementation | Mix methods | Preservice mathematics teachers | * | Scale and Interview | Hands on and STEM building sets | Turkey |
| Yıldırım & Türk (2018) | Implementation | Qualitative | Preservice primary teachers | * | Interview | Hands on | Turkey |

**Appendix 2.** Scale development and adaptation studies

| **Study** | **Scale development** | **Scale adaptation** | **Scale developed or adapted** | **Subjects** |
|---|---|---|---|---|
| Hacıömeroğlu & Bulut (2016) | | ✔ | Validity and reliability of the Turkish version of the "Integrated STEM Teaching Intention Scale" developed by Lin and Williams (2015) | Preservice primary teachers |
| Buyruk & Korkmaz (2016) | ✔ | | STEM Awareness Scale | Preservice Mathematics, Information technologies and science teachers |
| Kızılay (2017) | | ✔ | The validity and reliability of the STEM semantic scale developed by Knezek and Christensen (2008) and validated and validated by | Preservice Mathematics and science teachers |

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|---|---|---|---|---|
| | | | TylerWood, Knezek and Christensen (2010) | |
| Yaman, Özdemir, Akar & Vural (2018) | ✔ | | Teacher Self-Efficacy Scale for STEM Practices | Preservice teachers |
| Lin & Williams (2015) | ✔ | | Integrated STEM Teaching Intention Scale | Preservice science teachers |
| Yıldırım (2018) | | ✔ | The reliability and validity of the Turkish version of the "Teacher efficacy and attitudes toward STEM survey-science teachers" developed by Friday Institute for Educational Innovation (2012) | Preservice science teachers |

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