



**Abstract.** *Professional development programs might affect teachers' perceptions of how STEM disciplines are interconnected. The purpose of this research was to examine the change in perceptions of science teachers particularly in disadvantaged schools, who participated in a practice-based professional development program offered in Turkey, about STEM, entrepreneurship, and E-STEM, and their experiences related to E-STEM. This qualitative research had a phenomenological design. The participants were totally 30 science teachers who were teaching in each of the seven geographical regions of Turkey. The data were collected through semi-structured pre- and post-focus group interview forms finalized after the expert review and pilot study. Furthermore, the science teachers were asked to keep a diary about the implementation process throughout the research. The data collected through focus group interviews were examined using content analysis and the data collected through the diaries were examined using descriptive analysis. The findings of the study indicate that the science teachers defined E-STEM as a process containing the aspects of entrepreneurship (communication, perseverance and determination, self-confidence, motivation, risk-taking, presentation, and marketing) more comprehensively compared to the pre-interviews.*

**Keywords:** *STEM education, E-STEM education, science teacher, teacher education*

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## EXAMINING CHANGE IN PERCEPTIONS OF SCIENCE TEACHERS ABOUT E-STEM

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### Introduction

Increasing the number of high school, university, and master students specialized in STEM subjects is very significant for economic development. The majority of STEM graduates are recruited in STEM jobs with high salaries growing rapidly. For instance, according to the Report written by the Office of the Chief Economist, Economics and Statistics Administration, U.S. Department of Commerce, holders of a degree in STEM earn higher salaries, regardless of whether they work in STEM professions or not (Noonan, 2017). Furthermore, the persons employed in STEM professions suffer from lower rates of unemployment compared to the workers employed in other fields. This means that STEM employees have higher employment security. Moreover, the students studying in any department related to STEM professions could easily accommodate themselves even when they are employed in non-STEM professions (Thomasian, 2011). As a consequence, it is the belief that having a career in a field related to STEM would improve personal life standards and economic well-being drives the students toward this field (Douglas & Strobel, 2014, p. 248). However, it is found out that males in general have more of a tendency to prefer STEM careers compared to females (Christensen & Knezek, 2017; Ergun, 2018; Unfried et al., 2014). Besides, according to a recent report (Mader, 2014), opportunities to learn about STEM are lacking at rural schools in Pennsylvania, West Virginia and Ohio. In fact, STEM education interplays with and promotes universal human rights, and great attention should be paid to STEM education, education for all, 21<sup>st</sup> century skills, and Carroll's model of school learning in order to support universal human rights because universal human rights are at the center of these four domains (Milner, 2015). This requires an effective, quality STEM education. For this purpose, the proficiency level of science and mathematics teachers in STEM education is important (Nadelson et al., 2013). The necessity particularly for teachers to receive in-service education in effectiveness of STEM education has been emphasized. Furthermore, it is stated that school culture has an extremely effective role in application of STEM (El-Deghaidy & Mansour, 2015). On this basis, one of the fundamental objectives of STEM education is to create a workforce having the skills necessary for being employed in STEM fields (Barakos et al., 2012).

Today, big inventions and technologies shaping our world require successful market launches. Professional ethics and intelligence are required for STEM and innovations to provide a desired product or service. It is considered that one should not be late for educating small children in a process of designing, starting, and managing a new enterprise for this purpose. It is observed that skill of entrepreneurship has been integrated in STEM education and it takes place in the literature in the form of E-STEM (Entrepreneurship-STEM) in recent years on the basis of this requirement. Entrepreneurship is a multi-directional phenomenon. Approaching the definitions that have been made from the past to date with respect to entrepreneurship with a historical point of view, it is observed that the concept of entrepreneurship has been used since the 16th century, and the term 'entrepreneur' in the Middle Ages referred to a person who manages big projects and uses the resources rather than taking risks while managing the projects. It has been stated that this concept started to be used in the field of architecture in the 17th century and became a term used more frequently in the field of economics in the 18th century, and the term entrepreneurship was used with its current meaning for the first time by a French economist Richard Cantillon in 1730 (Ahmad & Seymour, 2008). Many distinguished economists (Adam Smith, Alfred Marshall, and Frank and so on) defined entrepreneurship by adding the leadership aspect and recognizing it through organization in the 19th and 20th centuries (Gautam & Singh, 2015). Entrepreneurship can be regarded as one of the 21st century skills (together with some other skills such as problem-solving, critical thinking, creativity, and innovation). Hence, entrepreneurship is associated with opportunities of perceiving, creating, and utilizing. Further fundamental elements are innovation and risk (Obschonka, 2014). One of the most recognized studies conducted on the 21st century skills is the classification of Partnership for 21st Century Skills (P21). According to the classification of P21, the 21st century skills consist of three main themes namely Learning and Innovating; Information, Technology and Media; Life and Career Skills (Partnership for 21st Century Skills, 2010). Adopting current approaches in teaching and welcoming science through STEM are the panacea for improving the 21st century education competencies (Polgampala et al., 2017).

Considering the definitions and characteristics of entrepreneurship, it is necessary to give significance to entrepreneurship education in order to train entrepreneur individuals with such qualifications. Entrepreneurship education was defined (European Commission/EACEA/Eurydice, 2016) as follows: "Entrepreneurship education is about learners developing the skills and mind-set to be able to turn creative ideas into entrepreneurial action. This is a key competence for all learners, supporting personal development, active citizenship, social inclusion and employability. It is relevant across the lifelong learning process, in all disciplines of learning and to all forms of education and training (formal, non-formal and informal) which contribute to entrepreneurial spirit or behaviour, with or without a commercial objective" (p. 21). Entrepreneurship education is defined as the processes or activities targeting at assimilating and developing the knowledge, skills, and values required for individuals to become entrepreneurs (Broad, 2007). According to Fayolle (2009), entrepreneurship education contains all activities targeting at developing mentalities, attitudes, and skills of entrepreneurship and covering the issues such as producing ideas, beginning, growing and innovation. According to Jones and English (2004), entrepreneurship education is the process of educating individuals with the capacity of recognizing commercial opportunities and insight and self-confidence. 32% of the definitions of entrepreneurship education in the literature emphasized having competency in the aspects of value, attitude, behaviour, and target determination for the purpose of being appreciated in the society and having a career. On this basis, the key concepts included in entrepreneurship education were stated as new job opportunities (18%); acquiring attitude, value, and behaviour (32%); developing management skills (9%); personal qualifications (32%); noticing the opportunities (9%). It has been targeted in the 2023 Education Vision Certificate to give young people the skill of social entrepreneurship within the learning-teaching process and to motivate them for seeking solutions to social problems and providing support for them through relevant teaching materials and media (Ministry of National Education, 2018a).

The findings have reflected that the majority of participants could not point out the reasons for including entrepreneurship in STEM. They have not pointed out how. The how part is important as pointed out by the Economic Research Institute for ASEAN and East Asia and Organisation for Economic Co-operation and Development (2004). Research studies combining STEM practices with different fields (science, art, health, computational thinking, religion, and so on) have been found in the literature. It is suggested that the development of entrepreneurship at early learning stages contribute highly to a country's economic development, and STEM issues are required to be associated with entrepreneurship in order to pave the way for sustainable economic development (Saiden, 2017). The main reason behind the integration of entrepreneurship and innovation into STEM is clarified as that mathematics has been intertwined and defined with the market economy in the transition process from the economy of agriculture and crafts to the economy dominated by industry and machinery manufacturing (Akinoso et al., 2020).



Integrating creativity, innovation and entrepreneurship into STEM education can help students develop interest in the subject matter and problem-solving skills and understand how the STEM work is related to real-world practices (Akinoso et al., 2020). Adding business and entrepreneurship programs to schools, especially in the context of STEM, can help students learn about future career opportunities by creating business ventures because entrepreneurship provides a real STEM learning context in which entrepreneurs translate innovative ideas into products and services through critical and creative thinking, problem solving, growth mindset, risk and uncertainty management, and resilience (Johnson & Mansfield, 2019). Correspondingly, STEM learning is targeted by new innovation and entrepreneurship programs (Schuelke-Leech, 2018). It can also be inferred that entrepreneurship is inherent in STEM applications because digital literacy, creative thinking, effective communication, high efficiency and moral values named as five domains in the 21<sup>st</sup> century skills nurtured by STEM as an interdisciplinary approach (Khalil & Osman, 2017) point out the skill of entrepreneurship. E-STEM applications have been performed in this research as well for integration of STEM with entrepreneurship. It is possible to say that the key competencies in all curricula in Turkey are structured to cover the skill of entrepreneurship in addition to STEM. Our education system aims at educating individuals with a character having knowledge, skills, and behaviours integrated with competencies. The competencies which are the range of skills that students will need both at national and international levels in their personal, social, academic, and professional lives have been determined in the Turkish Framework of Competencies (TFC). The TFC has determined eight key competencies. Those fields of competencies are listed as communication in the mother language, communication in foreign languages, mathematical competency, fundamental competencies in science/technology, digital competency, competency in learning how to learn, social competencies, competencies related to citizenship, competencies in taking initiative and entrepreneurship, and competency in cultural awareness and expression (Ministry of National Education, 2018b). One may say that E-STEM particularly and directly serves to give mathematical competency, competencies in science and technology, digital competency, competencies in taking initiative and entrepreneurship. Teachers are expected to have those competencies themselves in order to help the students acquire.

Teachers taking place in STEM education must learn more about the STEM fields and begin to show the students how they are connected. To do this, the author asserts that teachers must be STEM thinkers who can make their students understand how STEM is connected to their daily lives. STEM thinking is “purposely thinking about how STEM concepts, principles, and practices are connected to most of the products and systems we use in our daily lives.” At the tertiary level, STEM education makes students more likely to go in search of STEM careers in order to respond to the expanding need for educated professionals in these fields (Reeve, 2015).

Through STEM Education, students are urged to develop their knowledge and critical thinking to face existing phenomena. Students will also be able to design advanced technology as an alternative solution. Apart from gaining new knowledge, students will be also urged to identify problems, describe scientific phenomena, and be able to draw conclusions from the empirical evidence they find through Scientific Literature. In the end, students will be more sympathetic towards their environment especially the science-related ones (Agustina & Setiawan, 2019).

Li et al. (2019) detected in the research where they have examined the articles related to STEM published in 26 journals from 2000 to 2018 that vast majority of the articles have been written by American researchers, the number of the articles published has gradually increased within the last five years, the participants of the research studies have generally been teachers and prospective teachers, quantitative or qualitative methods have generally been used in the research studies, and the articles have been related to career, interest, attitude, and belief toward STEM as well as definition and assessment of STEM projects.

#### *Research Focus*

Examining the literature, various research related to STEM in teacher education aspect (Felix, 2010; Han et al., 2015; Sungur Gül & Marulcu, 2014; Tao, 2019) was found and very little research related to E-STEM was accessed (Deveci, 2019; Eltahany, 2019; Ruiz González et al., 2019). Eltahany (2019) tried to develop basic entrepreneurship competencies of the high school students in the United Arab Emirates applying the E-STEM model in his research related to E-STEM. It was observed as a consequence of the research that the high school STEM teachers believed that entrepreneurship could be integrated in STEM education through applications related to professional life, the E-STEM model developed the students' knowledge skills and attitudes related to entrepreneurship, entrepreneurship emphasized as the effect of E-STEM applications on learning output became a new learning tendency. Similarly Deveci (2019) underlining entrepreneurship aspect of STEM researched the effect of E-STEM process on



prospective science teachers' life skills (analytic thinking, decision making, creative thinking, entrepreneurship, communication, team work) and detected that the E-STEM process developed the skills of decision making, analytic thinking, creative thinking, communication, and entrepreneurship but adversely affected the skill of teamwork. The E-STEM process was detected to develop the skills of research, innovative thinking, risk taking, psychomotor skills, and problem solving as well. It was concluded that the E-STEM process taught the prospective science teachers to look with an interdisciplinary viewpoint, to be patient, and to act in a planned manner. Ruiz-González et al. (2019) concluded that the entrepreneurship education program containing a series of workshops based on active learning approach for the purpose of producing innovative solutions to real life problems adversely affected the perceptions of STEM teachers and students for determining enterprise opportunities, their entrepreneur environment awareness, and self-efficacy.

Numerous countries that desire for an advanced economy and technology aim to set up a society advanced in Science, Technology, Engineering, and Mathematics (STEM) and develop sustainably in these fields, and this has been the key educational strategy of the countries including Turkey as well (Türk et al., 2018). In the midst of harsh conditions, STEM as a trend is growing slowly but steadily in developing countries, but it becomes alarming in some developed countries. It is difficult for STEM teachers to adapt recent trends such as integration into their classrooms. Professional development of teachers in STEM fields is in high demand to help them teach STEM effectively in an integrated context (Sandall et al., 2018). Therefore, STEM professional development programs of high quality are urgently needed (Polgampala et al., 2017). It is claimed that successful STEM implementation requires research-based teacher education and professional development. Research-based STEM teacher education plays a significant role in making modern reforms and doing evidence-based educational research to study the effect of STEM teacher education on the development of teacher knowledge and student learning (Milner-Bolotin, 2018). There are few professional development opportunities which provide in-service teachers with STEM content knowledge and guidance (Tao, 2019). In-service teachers should be informed about the effective instructional strategies used to do project-based learning (PBL) activities and be supported to plan and implement STEM PBL lessons preferably through continuing professional development programs (Han et al., 2015). The in-service education programs applied to the teachers in Turkey have been determined to be theoretical in general, their efficiency has been low, the subjects have not been found to be understandable, and teachers have been expected to have practical in-service education (Sarigöz, 2011). Practical E-STEM education thought to contribute to their professional development within a research-based process was given within the scope of this research. This research was an output of the project titled "Entrepreneur Teacher Education: E-STEM" granted by Scientific and Technological Research Council of Turkey (TUBITAK).

### *Research Aim and Research Questions*

The purpose of this research intended to fill the gap in the literature was to profoundly examine the perceptions of science teachers particularly in disadvantageous schools with respect to STEM, entrepreneurship, and E-STEM and their experiences related to E-STEM. The responses to the following research question were sought on the basis of this purpose:

- How did the "Entrepreneur Teacher Education: E-STEM" project affect the perceptions of science teachers toward
- STEM
  - Entrepreneurship
  - E-STEM?

## **Research Methodology**

### *General Background*

This was a qualitative study aiming at profoundly examining the perceptions of science teachers in disadvantageous schools with respect to STEM, entrepreneurship, and E-STEM and their experiences related to E-STEM. The design of the research was phenomenology. Phenomenology provides opportunities to explore, describe, and analyse the meaning of an individual lived experience (Marshall & Rossman, 2006), which herein was E-STEM. This study aimed to gain deep insight into "how they perceive it, describe it, feel about it, judge it, remember it, make sense of it, and talk about it with others" (Patton, 2002, p. 104) and how they experience it (Bogdan & Biklen, 2007).



Therefore, this research made it explicit how the perception of E-STEM depends on teachers' experience (Yüksel & Yıldırım, 2015). Perceptions of science teachers were studied because perceptions bring new perspectives to consciousness, and the whole process takes on the character of curiosity, as the knowledge that unites the past, present, and future, and gradually expands and deepens what it is and what it means (Moustakas, 1994). Regardless of the judgments made, they are always dependent on ideas as people do not make judgments independent from ideas anywhere in the experience (Husserl, 1973 cited in Moustakas, 1994). Smith (1982, p. 57) underlined the significance of perception as follows: "What we have in our heads is a theory of what the world is like, a theory that is the basis of all our perceptions and understanding of the world, the soul of all learning, the source of all hopes and fears, motives and expectancies. And this theory is all we have. If we can make sense of the world at all, it is by interpreting our interactions with the light of our theory" (cited in Marzano, 1992, p.4). Phenomenology crystallizes the phenomena which are noticed but not understood profoundly (Yıldırım & Şimşek, 2016). Phenomenological research may be defined as the common meaning of the experiences of several persons with respect to a phenomenon or concept (Creswell, 2013). The research was conducted between July and December in 2019.

### Participants

The process of data collection generally contains the interviews with the individuals who have experienced the phenomenon in phenomenological research studies (Creswell, 2013). The study group was composed of totally 30 science teachers determined through the maximum variation sampling method. In this research, six focus groups were formed each of which had five participants. According to Creswell (2012), a focus group interview is the process of collecting data through interviews with a group of people, typically four to six. In addition, as suggested by Creswell (2013), the study group can consist of 5-25 participants in phenomenological research. While 11 of the participants were teaching in the province of Afyonkarahisar, 19 of them were on duty in one of the seven geographical regions of Turkey. While determining the teachers, it was considered that they had never received STEM and/or E-STEM education before and they worked in disadvantaged schools. STEM education especially for the Disadvantaged is widely known as central to economic development and security in the long term (Xie et al., 2015). The characteristics of science teachers participating in the research are indicated in Table 1.

**Table 1**  
*Characteristics of the study group*

Participant/Focus Group (FG) Number	Gender	Length of service	Education level	Province of office
Ferdi/FG6	Male	13-15 years	Master's Degree	Afyonkarahisar
Mahmut/FG1	Male	7-9 years	Bachelor's Degree	Afyonkarahisar
Nisan/FG2	Female	7-9 years	Bachelor's Degree	Istanbul
Mücahit/FG6	Male	7-9 years	Master's Degree	Aksaray
Ayza/FG3	Female	10-12 years	Bachelor's Degree	Antalya
Kevser/FG1	Female	4-6 years	Bachelor's Degree	Afyonkarahisar
Yasin/FG4	Male	7-9 years	Bachelor's Degree	Afyonkarahisar
Haktan/FG6	Male	7-9 years	Bachelor's Degree	Yozgat
Sevil/FG4	Female	7-9 years	Bachelor's Degree	Afyonkarahisar
Sevgil/FG3	Female	7-9 years	Bachelor's Degree	Samsun
Metin/FG2	Male	7-9 years	Master's Degree	Izmir
Özge/FG1	Female	13-15 years	Master's Degree	Ankara
Nil/FG4	Female	7-9 years	Bachelor's Degree	Hatay
İsmail/FG4	Male	7-9 years	Bachelor's Degree	Sanliurfa
Tülay/FG3	Female	4-6 years	Bachelor's Degree	Afyonkarahisar
Şeref/FG1	Male	7-9 years	Bachelor's Degree	Diyarbakir



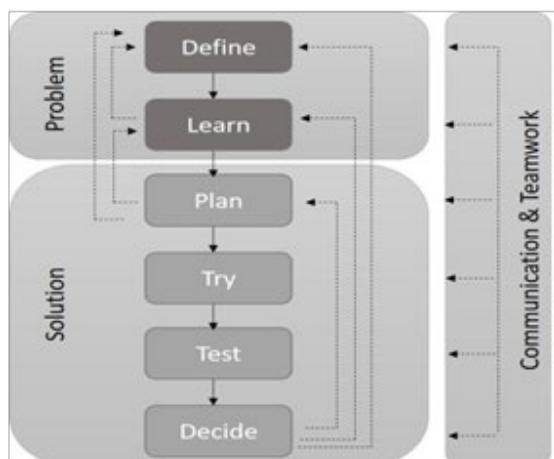
Participant/Focus Group (FG) Number	Gender	Length of service	Education level	Province of office
Abdullah/FG2	Male	4-6 years	Master's Degree	Istanbul
Tansu/FG5	Female	7-9 years	Master's Degree	Afyonkarahisar
Mert/FG3	Male	4-6 years	Bachelor's Degree	Kayseri
Ümmühan/FG5	Female	4-6 years	Bachelor's Degree	Sakarya
Sinan/FG2	Male	4-6 years	Bachelor's Degree	Afyonkarahisar
Mesut/FG4	Male	10-12 years	Master's Degree	Manisa
Elif/FG1	Female	4-6 years	Bachelor's Degree	Artvin
Beril/FG6	Female	0-3 years	Bachelor's Degree	Mardin
Sabri/FG3	Male	16-18 years	Bachelor's Degree	Afyonkarahisar
Nurdan/FG6	Female	10-12 years	Bachelor's Degree	Afyonkarahisar
Utku/FG5	Male	13-15 years	Bachelor's Degree	Afyonkarahisar
Hüseyin/FG5	Male	4-6 years	Bachelor's Degree	Sakarya
Meliha/FG2	Female	4-6 years	Bachelor's Degree	Antalya
Defne/FG5	Female	7-9 years	Bachelor's Degree	Agri

As seen in Table 1, 15 of the science teachers in the study group are female and 15 are male; 23 have bachelor's degree and seven have master's degree; 23 have experience of less than 10 years and seven have experience of more than 10 years; 11 work in Afyonkarahisar (where the project was carried out) and 19 work in cities situated in different geographical regions of Turkey (Agri, Aksaray, Ankara, Antalya, Artvin, Diyarbakir, Hatay, Istanbul, Izmir, Kayseri, Manisa, Mardin, Sakarya, Samsun, Sanliurfa, and Yozgat). About one third of the science teachers were working in Afyonkarahisar which was the research site selected by convenience because all of the researchers were teaching in this city. As qualitative studies mostly aim to gain a deeper insight into human experience studying particular cases intensively rather than to generalize the findings (Polit & Beck, 2010), this imbalance in the number of participants would not cause any threat to generalizability of the findings.

### *Research Implementation*

First of all, the learning outcomes were drawn from the curricula of the courses of Science, Technology and Design, Mathematics, and Information Technologies and Software. E-STEM plans were developed, and preparations for the implementation process were performed in the process of research. The scenario in these plans was developed through adaptation from the project numbered NSF DRL-1238140 and named "EngrTEAMS: Engineering to Transform the Education of Analysis, Measurement, and Science in a Team-Based Targeted Mathematics-Science Partnership" (Moore & Douglas, 2016). The list of the materials necessary for the project (K'nex sets, lab equipment, and so on) was formed and procured in this process, the opinions of the experts were received, and preparations for the implementation process were completed. The theoretical educations given by the researchers working in the fields of E-STEM related to the five fundamental disciplines (field experts) were completed on the first day of the project. From the second day on, the workshops and E-STEM implementation process were started, and the participants were enabled to carry on the studies using the engineering design notebooks actively in the workshops performed considering the basic phases of the "Engineering Design Process" till the end of the implementation process. The researchers undertook the task of guidance in the implementation process where collaborative works predominated.



**Figure 1***Engineering design process (Moore & Douglas, 2016)*

The activities performed in each phase of the engineering design process appearing in Figure 1 were explained in detail as follows:

- (1) **Define:** The science teachers participating in the project were presented the situation of problem with a scenario. The teachers were enabled to notice and define the situation of problem through collaborative works, the engineering design notebooks were introduced to the teachers, and they were given information about how to use them in the process.
- (2) **Learn:** Before starting the engineering design process with the teachers, practices for discovering magnets and materials with magnetic properties were performed. In this context, teachers used various materials and made experiments to test their magnetic properties. They recorded the data on the experiments they made in the engineering design notebooks.
- (3) **Plan:** The teachers determined and tested the different variables that affect the power and performance of electromagnets and performed studies on which one to select. They showed and presented the data obtained in the performance tests on electromagnets in tables and graphs. The electromagnet selection was decided as a consequence of the discussions among the groups.
- (4) **Try:** The teachers sketched a prototype on paper using the information they learned about magnets and electromagnets on the basis of the scenarios presented to them. After group discussions, the malfunctioning aspects of the design were determined and revised. The groups justified their own design preferences on the basis of the following aspects of entrepreneurship: "innovation and creativity", "pro-activity", and "resource management".
- (5) **Test:** The teachers later performed their trials as requested in the scenario. In the later phase of the testing, the teachers continued testing and were enabled to make the necessary modifications in their designs in accordance with the "innovation, assessment, development" aspects of entrepreneurship.
- (6) **Decide:** After the teachers tested their electromagnets, they expressed their decisions on the basis of the data they collected. After completing testing, the teachers prepared presentations adapting their designs to different needs on the basis of social entrepreneurship, environmentalist entrepreneurship, and original entrepreneurship aspects. The teachers were asked to present the posters they designed and advertise films using different programs (Canva, Powtoon, and so on). The teachers were enabled to be involved in each of the "persuasion and communication", "developing marketing strategies", "competitive thinking", and "adaptation to different areas" aspects of entrepreneurship. The commission assessed the presentations and announced the team to be awarded as specified in the scenario. Some of the photographs which are representative of each stage of the engineering design process are depicted in Figure 2 (see Appendix 1).



### *Instrument and Procedures*

The data were collected through semi-structured pre- and post-interview schedules finalized after receiving the opinions of science teachers and experts. Thirty science teachers who participated in the research were divided into six focus groups as five teachers in each group, and the data were obtained through the focus group interviews held by the researchers. Group interviews are used to receive the answers of groups consisting of several persons in order to discover the shared viewpoints or experiences. Group interviews are usually referred to as the focus group (Lodico et al., 2010). Furthermore, the science teachers were asked to keep a diary about the implementation process throughout the research. The teachers wrote diaries where they reflected their opinions on the process at the end of each day throughout four days when the workshops were held. Totally 120 diaries obtained at the end of the research were dealt as documents. Personal documents are explained as the acts, experiences, and beliefs of persons. Personal documents include journals, diaries, letters, development records of children, albums, calendars, autobiographies, and travel notes (Hodder, 2000). Diaries were used in this research as a tool of data collection within the scope of personal documents.

Pre- and post-interviews were held with a focus group consisting of five science teachers in the pilot scheme, and the interview forms were reviewed and improved on the basis of the opinions of the focus group. Three of the researchers collected data through semi-structured interviews with the six focus groups created using the pre-interview form on the first day of the real implementation of this project and using the post-interview form on the fifth day. Each of three researchers moderated only two of six focus groups interviewed consecutively. The six focus groups consisting of five teachers each were provided the necessary physical conditions to make them feel relaxed for the interview, and the participant teachers were given equal words as a principle. The pre-interviews lasted for 23.89 minutes on average, and post-interviews lasted for 29.32 minutes on average. Furthermore, the diaries kept by the teachers who participated in the research from the second day of the implementation process provided data for the research as well.

### *Data Analysis*

The data collected through focus group interviews were examined using content analysis and the data collected through the diaries were examined using descriptive analysis. In content analysis known as latent analysis (Bengtsson, 2016), 'core consistencies and meanings' (Patton, 2002, p. 453) inherent in themes developed from codes assigned to represent data are explored and merged into a meaningful whole (Miles & Huberman, 1994). In descriptive analysis, known as manifest analysis (Bengtsson, 2016), the researcher describes what the participants actually say and what is apparent and clear in the text, staying very close to it, and using the words themselves. After the semi-structured pre- and post-interviews were transcribed, all data were coded using inductive coding and the relevant codes were collected under appropriate themes. The data obtained through the diaries were coded using deductive coding and described under the predetermined themes.

### *Data Trustworthiness*

In order to provide cogency of the data (Miles & Huberman, 1994), semi-structured pre- and post-interview forms were prepared by receiving expert opinion and experimented in the pilot scheme. The questions in pre- and post-interview forms were reviewed and improved as a consequence of the pilot scheme. In order to provide transferability of the data (Miles & Huberman, 1994), maximum variation sampling method was preferred among the sampling methods, and the data were described as detailed as possible and presented together with direct citations (Lincoln & Guba, 1985). Confidentiality of the participants was provided by giving each teacher a code name (such as Ayza, Sinan). Recording the interviews using a voice recorder prevented data loss. The interview questions were asked by the interviewers to each teacher in the focus group with the same tone of voice and words in order to assure consistency, and a randomly selected interview was coded separately by the researchers (LeCompte & Goetz, 1982). Calculation of the accord among the co-coders as 92% indicated that consistency was provided at a high level (Miles & Huberman, 1994).



### *Ethical Considerations*

Permission of the Scientific Research and Publication Ethical Board of Afyon Kocatepe University was received firstly in the phase of data collection. Since science teachers were positioned at the focus of the research, the science teachers were informed through a consent form about the nature of the research, potential risks, and estimated length of the interviews. Permission was received from the science teachers to participate in the research and record the interviews using a voice recorder. It was declared that the data collected would be kept confidential.

### *Role of the Researchers*

The researchers assumed the role of a data collection tool in the interview process. They paid care for their personal assumptions and prejudices not to influence the data to be collected.

## **Research Results**

The content analysis of the data collected as a consequence of the pre- and post-interviews carried on with the science teachers who participated in the project make up the following five sub-themes in Table 2. The data obtained from the pre- and post-interviews are supported with the findings obtained through the descriptive analysis of the data collected through diaries.

**Table 2***Perceptions of science teachers on (E-)STEM*

Theme	Sub-themes
Perceptions of the science teachers with respect to (E-)STEM	Perceptions with respect to the definition of STEM
	Perceptions with respect to integration in E-STEM
	Perceptions with respect to the definition of entrepreneurship
	Perceptions with respect to the properties of the E-STEM process
	Perceptions with respect to the achievements provided by the E-STEM process

As seen in Table 2, the perceptions of the science teachers with respect to (E-) STEM have been collected under the sub-themes of (1) perceptions with respect to the definition of STEM, (2) perceptions with respect to integration in E-STEM, (3) perceptions with respect to the definition of entrepreneurship, (4) perceptions with respect to the characteristics of the E-STEM process, and (5) perceptions with respect to the achievements provided by the E-STEM process.

### *Perceptions with Respect to the Definition of STEM*

The science teachers who participated in the project defined STEM in the pre-interviews as a process and approach. The science teachers who defined STEM as a process stated that this was a process allowing scientific, creative, and active learning, and the teachers who defined STEM as an approach stated that this was an approach of interdisciplinary teaching.

#### *STEM as a process of scientific, creative, and active learning*

The science teachers who defined STEM as a process associated this mostly with the process of problem solving as follows:

It is to be able to produce different solutions using the materials for a problem of daily life (FG3).

STEM is a process which suggests how we should solve a problem in daily life in a more systematic manner (FG6).



While defining STEM in the final interviews, the science teachers who participated in the project emphasized that STEM was a process, this process was scientific, and they solved the problems using a scientific method within this process. The science teachers expressed their opinions about scientific aspect of the STEM process as follows:

It is a scientific study in the centre of which science course is situated because we try to solve a problem and we try to achieve the most correct result through numerous trials. We collect data. We perform a scientific study (FG6).  
It is combining the disciplines and producing solutions for any problem (FG4).

The science teachers expressed in their diaries that the process of E-STEM was an amusing and active process of learning as follows:

The process has become amusing from the moment when we were involved in the implementation process. Entertainment and learning increased in line with the increase in active participation (FG5).  
I liked learning by trying and experiencing is much more pleasing (FG2).

Furthermore, the science teachers mentioned that the STEM process was creative, creative ideas were created in this process, and this triggered group study. The science teachers' opinions on creativity of the STEM process were as follows:

I also think that group work had positive [...] on creativity. I believe that more creative ideas will be produced when we motivate the students to work within a group and persuade them to work with a group, and they will develop themselves in this regard (FG2).  
Here, we observed that very creative ideas were really produced in group work when the individuals within the group involved in the process (FG2).

A science teacher reflected the fact in his/her diary that the E-STEM process and particularly technology discipline developed creativity:

I observed that K'nex sets quite supported creativity, we constructed two towers; I suppose that we have solved the problems of balance using the K'nex set effectively (FG1).

#### *STEM as an interdisciplinary approach*

As follows, the science teachers who perceived STEM as an approach rather than process in the pre-interview expressed that this approach was interdisciplinary or holistic:

Science, technology, engineering... an interdisciplinary approach (FG3).  
We can express STEM as an interdisciplinary approach (FG4).

Even there were a few science teachers who expressed in the pre-interviews that integration of STEM disciplines could be necessary for affective and psychomotor learning and transfer of what was learned. The opinions of those teachers were as follows:

I consider that students will begin to develop a positive attitude toward the lesson [...] such type of activities (FG3).  
It contributes to the psychomotor skills (FG4).  
E-STEM can enable us to adapt any knowledge or result that we acquire from a field to any other field or problem (FG5).

#### *Perceptions with Respect to the Integration in E-STEM*

The science teachers expressed their opinions on the fact that E-STEM disciplines are already a whole in the final interviews as follows:

I realized that the disciplines are already a whole. Now I think that we have divided them. Namely, these are such



disciplines that should not be separated from one another. Both the discipline of mathematics and science as well as design and engineering... Indeed, all of these are [...] disciplines, I think. I suppose we made a mistake by separating them (FG2).

I also discovered that they are more intertwined. In plain words, just like... I used to say there is mathematics here and there is science there but now when I am asked, I think that all are intertwined (FG2).

The science teachers expressed in the final interviews that integration of E-STEM disciplines could be necessary for production and presentation:

It is necessary for producing different products in STEM (FG3).

I believe that entrepreneurship could be activated fully in the phase of promoting the product, in the phase of presentation of the studies conducted (FG6).

The opinions of the science teachers believing now that E-STEM disciplines were required to be integrated are as follows:

If you told me before receiving this education "Let's include entrepreneurship in education", I would answer "Do we perform trade? Will we train marketers?"; I would think we should give the children more proper theoretical knowledge with more level-headed ideas etc. but after receiving this education I realized significance of educating more entrepreneurial individuals who try to challenge themselves a bit in every field of life or who try to go beyond the boundaries (FG4).

In line with the data of semi-structured interviews held with the science teachers, it was understood from the diaries which the teachers kept throughout the project that engineering, technology, and entrepreneurship were dealt among the definers of the E-STEM process. The science teachers stated as follows that the E-STEM process was a process where the problem was defined in terms of the engineering discipline and which was aesthetic, amusing, but tiring:

After determining the problem in the engineering design process, we started the studies where we performed our own implementations. This section was more fluent and amusing (FG4).

We got quite tired in the process of planning and trying (FG1).

The science teachers who expected to learn coding expressed in their diaries that the E-STEM process was a pleasing and useful process in terms of technology discipline as follows:

I learned K'nex for the first time owing to this project. It is very nice and amusing. Just like the Lego that we used to play in the past... (FG2).

We learned the coding program. We wrote codes. It was very pleasing to acquire new skills in this regard (FG6).

#### *Perceptions with Respect to the Definition of Entrepreneurship*

The science teachers defined entrepreneurship in the pre-interviews as limited to a few aspects (production, presentation, marketing, and adaptation). The science teachers' definitions with respect to entrepreneurship were as follows:

To produce products for needs with lower costs and within a shorter time and present the same. Presenting or marketing, both are possible (FG5).

What kind of a problem does the product produced provide a solution for? It is an adaptation of the product produced to different fields (FG3).

The science teachers stated in their diaries that the E-STEM process was a process containing the aspects of entrepreneurship (communication, perseverance and determination, self-confidence, motivation, risk taking, presentation, and marketing), and their opinions were as follows:



Some synergy was created between me and my group friends while we tried to reach a conclusion in the trials we performed (FG6).

After the towers were constructed, coding of the gripper in the computer remained to be performed. Our inexperience in MBlock use coerced us very much and we continued with trial and error helplessly. Finally, we achieved (FG1). Performing presentations related to our products and answering the questions asked increased our self-confidence. This allowed us standing behind the work we performed and defending it (FG3).

The section of adaptation of the product we designed motivated us very much with regard to entrepreneurship. I could say that it was a section where we tried to show ourselves more (FG3).

I realized that risk taking, calculating the probabilities are as important as producing a product, and the real success is using the product in different fields taking risks (FG4).

### *Perceptions with Respect to the Properties of the E-STEM Process*

#### *Group work*

As one of the descriptors of the E-STEM process, the group work was reflected in the diaries which science teachers kept throughout the projects. The science teachers mentioned that group work was motivating and instructive, and it allowed discussing different ideas, developed thinking, made one feel empathy, allowed one to discover different skills, allowed one to solve a problem, activated one, broadened one's viewpoints, and allowed one to work in harmony.

We learned certain subjects through trial and error within the process together with the team (FG1).

Performing group works contributed to assessing the events through different viewpoints and feeling empathy (FG5).

We encountered many problems, but we overcame all problems with collaboration (FG4).

I realized in my education today that team- work produced more positive results in terms of developing creative thinking. I felt content for being in a team giving importance to its work (FG2).

Our innovative and critical thinking skill developed (FG3).

The science teachers who participated in the project stated in their last interviews that one of the pleasing aspects of the project was the creation of the groups. They further stated using the following sentences that the process developed the solidarity among the teachers and assisted the teachers with completing one another:

I really think that we created a group composed of people with different qualifications. If I want to receive such education once more, I would like to work with a group which could provide such integration. First of all, I say this sincerely. We really compensated one another's deficiencies very well. At that point, I thanked my friends. I congratulate them (FG3). A nice group was created. We had such a nice group for the first time. Namely, we were thankful to the tutors. This solidarity, this study was great (FG2).

### *Perceptions with Respect to the Achievements Provided by the E-STEM Process*

#### *Learning how the E-STEM process was applied*

The science teachers who participated in the project stated in the pre-interviews that they expected to learn how to implement the integration of the E-STEM disciplines. Their opinions were as follows:

But I came in order to learn how I could place this in the science curriculum, how I could associate it with mathematics and engineering as well as the relevant methods (FG2).

This is named as E-STEM. Namely, because it shall contain entrepreneurship to some degree... I'm a graduate student. I will definitely take something from this and contribute to my education (FG4).

The science teachers stated in the final interviews that the project contributed to their learning. The science teachers who stated that they learned how the E-STEM process was applied specified that they particularly learned



how the engineering design process was operated, how to prepare posters and that the group work was significant, the process was more important than the product, and that the coding is necessary as follows:

I learned that engineering design processes were available in STEM with higher rates than I had expected and that they were more important. Surely, I realized my own deficiencies as well (FG1).

Before coming here, product was very significant for me in STEM. I believed that a proper product should be produced. However, after the implementation, I learned that the process was significant, rather than the product (FG6).

The science teachers stated that they gained awareness about the significance and operation of the E-STEM process in the sentences they wrote in their diaries:

I understood much better what STEM implementations are, which characteristics they should have. Now I consider that I have achieved the level of knowledge and skill that I could discriminate which implementations and activities are STEM and which are not (FG1).

I better comprehended how the concepts of science-mathematics-engineering-entrepreneurship were intertwined in STEM and that they were a whole (FG2).

#### *Learning with trial and error/from mistakes*

The science teachers reflected in their diaries that they learned with trial and error throughout the project with respect to contribution of the project to learning. Their statements were as follows:

I can clearly say that we learned from the mistakes we had made (FG5).

The results which we reached through different trial and error processes were good. I think that we achieved the desired result by acquiring the best result with the trial and error processes and the infinite energy of the group (FG6).

#### *Constructivist learning*

There were also science teachers who reflected their thoughts regarding the contribution of the project to learning in their diaries that learning based on the constructivist approach realized in the E-STEM process. The science teachers expressed in their diaries that they had cognitive imbalances in the E-STEM process and realized that they had concept mistakes, as follows:

Everything is great but I experienced quite a lot of confusion. I even thought for a moment that I forgot everything that I had known (FG1).

We have learned through experiencing the mistakes known about magnets and the things known incorrectly by the students (FG6).

#### *Transfer*

The science teachers expressed that they expected from the project to help them transfer what they learned, as follows:

How could I adapt it to daily life? I participated in order to see this (FG1).

Such hobbies, such works, and such projects of ours shall definitely increase when we participate in the STEM studies (FG1).

Furthermore, science teachers expressed that they could transfer what they learned owing to the project.

I experienced that theoretical knowledge gains meaning when it is transformed into implementation (FG3).



### *Thinking*

The science teachers expressed in their final interviews that the project contributed to thinking as well. With respect to the contribution of the project to thinking, the science teachers suggested that they could think more reflectively, empathically, and multi-dimensionally thanks to the project. The science teachers expressed that they could feel empathy with their students in the E-STEM process as follows:

At the beginning I was thinking about the end when the problem was being given to us. We achieved a result which I could never have imagined but now I think that knowing the result contributes much on behalf of me in terms of orienting the students while giving them the phases or guiding them (FG2).

I learned on this basis at which phases the students got bored. Which step should not I take? Which phase could attract their attention more? Since it was applied on me as well, I put myself in their shoes and could better analyse the process (FG6).

The science teachers reflected in their diaries that the E-STEM process developed emphatic thinking as follows:

This process that I have experienced allowed me to develop ideas about what the students could feel, how much time they could need, how difficult or easy it could be to achieve the result (FG2).

I would like to express that I have great difficulty as a teacher (in the role of student) and sometimes I come to the point to cry "Enough, I will leave!" Sometimes I even thought about what could be done to sustain the students' motivations while they experience this process (FG1).

The science teachers expressed with the following words that they could think reflectively in the E-STEM process:

Well, I realized my own deficiencies. I still have some. I have deficiencies in computer programs (FG1).

I observed my own deficiencies. I have plenty of deficiencies. I realized those deficiencies. What did I know falsely in this process? I learned what STEM was (FG1).

The science teachers further expressed in their diaries that the E-STEM process developed reflective thinking and they particularly realized their own deficiencies related to the discipline of technology, as follows:

As a science teacher, I have plenty of deficiencies in the section of technology. There are many deficiencies in the section of coding (FG1).

The science teachers stating in the pre-interviews that they expected from the project to make them think multi-dimensionally expressed with the following words that they could look through the problems from different perspectives in the E-STEM process and they could think multi-dimensionally:

I learned looking multi-dimensionally in this education. Namely, when you look through any problem from a single dimension you could make mistakes. I discovered that I should look multi-dimensionally. Try this once, and how the results of the experiment... I discovered that it is significant to keep the control variables stable (FG2).

I saw how many different points of view could develop us (FG3).

### *Professional development*

The science teachers who participated in the project expressed with the following words in the pre-interviews that they participated in the project for the purpose of contributing to their professional development and they expected that the project would contribute to their professional development:

Does it contribute to me in professional terms? Will it be useful for me while I perform the profession of teaching? I think that I have great trouble when I have the children to perform any project and when I conduct a project. I think that the children are sufficient as well. I participated hoping that it could be useful (FG4).



The science teachers reflected in their diaries that the E-STEM process contributes to their professional development, and their opinions were as follows:

It was satisfactory in terms of being an education which largely contributes to my professional development (FG6). I consider that I worked with a team with high energy and gained experience through my successes and failures. At the end of this education, I will try to perform this education as well in the organization where I'm employed (FG6).

## Discussion

The purpose of this research was to profoundly examine the perceptions of science teachers with respect to STEM, entrepreneurship, and E-STEM. It was determined as a consequence of the research that the science teachers defined STEM as a scientific, creative, and active learning process and as an interdisciplinary teaching approach. Those perceptions may be associated with the fact that the research implementation process was performed through workshops where the teachers were active rather than in the form of a theoretical education. Consequently, one may say that the perceptions and experiences of the teachers coincided. Margot and Kettler (2019) concluded that teachers found out that the engaging and authentic nature of interdisciplinary STEM education was potentially beneficial. El-Deghaidy et al. (2017) found out that teachers perceived STEM as an interdisciplinary approach according to one of the themes emerged from the data collected through focus-group interviews. As mentioned by Bozkurt-Altan and Ercan (2016), professional development programs had a positive influence on teachers' views about STEM education, and the teachers suggested the (engineering) design-based science instruction for adopting STEM education.

The science teachers defined E-STEM as a process containing the aspects of entrepreneurship (communication, perseverance and determination, self-confidence, motivation, risk taking, presentation, and marketing) more comprehensively compared to the pre-interviews. It was tried in this research to enable teachers to be competent in the fundamental aspects of entrepreneurship throughout the implementation process within the scope of E-STEM and they were made to prepare advertising films and posters for marketing their designs produced in the E-STEM process at the end of the implementation process. Furthermore, it was considered that this positive change in their perceptions with respect to entrepreneurship was caused by failure of the science teachers to receive any education related to STEM, entrepreneurship, or E-STEM and due to the fact that they had such experience for the first time thanks to this education. Nadelson and Seifert (2019) have suggested teaching and learning integrated STEM using andragogy to develop an entrepreneurial mindset in the age of synthesis. In other words, using the instructional approach in which students are given a problem to solve and are encouraged to decide on how to approach, develop and test a solution; teachers can help students gain 21st century skills, be entrepreneurs, and have a growth mindset. Similarly, Hixson et al. (2012) concluded that STEM education was effective in understanding the aspects of entrepreneurship. In addition, the science teachers stated group work as one of the definers of the E-STEM process after the project. Collaboration is the most essential component of the STEM fields (Bughin et al., 2010). The science teachers expressed that group work was a motivating, instructive, emphatic, and active process, provided multiple perspectives, and contributed to compatible work and problem solving. Wang et al. (2011) stated that collaboration among the learners is necessary in STEM within the process of combining the disciplines and solving real life problems. Freeman et al. (2008) concluded that collaboration fostered the quality of learning and motivation in STEM. The science teachers expressed as well that integration of the E-STEM disciplines was necessary. Emergence of this situation may be explained with the fact that the researchers guiding the groups have fields of specialization which would cover all five disciplines of E-STEM and that the researchers reflect their field knowledge related to those disciplines to the process as a whole rather than independently from one another. After the implementation process, the teachers who mentioned the significance of the integration of disciplines one by one before the E-STEM implementation process emphasized that integration of those disciplines should have a gift structure. This is in harmony with the analogy in the statement of Lederman and Niess (1997, p. 57): "If cooking is your forte, integration is analogous to tomato soup. The soup simply appears as a homogeneous liquid."

This study indicated that science teachers' perceptions about E-STEM have been changed based on their experiences. The science teachers stated that they learned how the E-STEM process was implemented, they



learned through trial and error/from mistakes, they learned according to the constructivist approach, they could transfer what they learned, and that they had professional development. The opinions of the science teachers that they learned how the E-STEM process was implemented may be interpreted as the natural result of the implementations performed in the “learn” phase of the engineering design process taken as the basis in the research, their expression that they learned through trial and error/from mistakes may be interpreted as the natural result of the implementations performed in the “try” phase, and their opinions on the development of thinking may be interpreted as the natural result of the implementations performed in the “decide” phase. The participants of STEM attributed at least some part of their success to their experiences with failure (Simpson & Maltese, 2017). According to Wang et al. (2011), professional development programs are significant to enable the teachers to combine the disciplines in STEM. Professional development programs can assist teachers to develop the essential teaching skills to do STEM project-based activities (Capraro et al., 2016). Felix (2010) emphasized in his research that the skills of implementing and learning the concepts of science from chemistry to environmental science, engineering design process, mathematical problem solving, data collecting and analysing, and technology using could be developed both in order to provide professional development of the science teachers and in order to develop student acquisition in STEM fields. Jho et al. (2016) shed light on the conditions for the successful implementation of STEM/STEAM teacher education in Korea with a case study on two schools from the community of practice paradigm as “open-mindedness, self-innovation, reciprocal relationship, continuous role exchange, educational materials, and abundant time” (p. 1843). Correspondingly, Sandall et al. (2018) structurally and interpersonally identified ten phenomena which were related to integrated STEM education as follows: “subject integration, project-based learning, and design-based education; STEM content; professional development; time; non-traditional assessment; collaboration; willingness; authentic, relevant, and meaningful experiences for educators and students; leadership; and outside support (by business, industry, and people)” (p. 32). Additionally, these ten phenomena were considered both critical and implementation factors as they are a necessary part of an integrated STEM curriculum and are critical to the creation and implementation of integrated STEM plans. Science teachers in Saudi Arabia admitted that STEM education can foster the development of 21st century skills that can be beneficial for selecting science-related careers (El-Deghaidy & Mansour, 2015). Coppola and Malyn-Smith (2006) stated that less attention to technology and engineering in STEM education as a barrier to choosing and pursuing a career in technology and engineering. In fact, technology and engineering activities develop STEM literacy and enhance motivation as well as provide authentic contexts for learning scientific and mathematical concepts (National Research Council, 2012). Although constructivism can be an infant in the multidisciplinary learning environment, the gap is closing along with the rise of STEM (Kara, 2019). When students perceive the learning environment as more constructivist, they are more likely to pursue science-related STEM careers (Wild, 2015). STEM develops meaningful learning and understanding through practical and collaborative activities and supports the constructivist theory (Whitehead, 2010).

The most striking finding of this research was that the education implemented in this research allowed teachers to develop professionally in the field of STEM and to increase their perceptions with respect to STEM, entrepreneurship, and E-STEM. Correspondingly, Nadelson et al. (2013) found out that the inquiry-based STEM professional development program had a positive impact on elementary teachers’ perceptions of STEM, confidence for, and efficacy for teaching inquiry-based STEM. In addition, Thi To Khuyen et al. (2020) concluded that Vietnamese teachers perceived positively STEM education, valued STEM competencies, but they felt difficulty implementing STEM education and emphasized that being a STEM thinker was a prerequisite to becoming a STEM teacher to sustain STEM education development and that professional development was needs for STEM thinking and awareness of STEM careers. After participating in a STEAM professional development program, mathematics and science teachers increased their perceptions about STEAM teaching and regarded the professional development in STEAM as an effective first step to alter the practice, referring to the significance of collaboration and direct integration of technology into learning (Herro & Quigley, 2017). Debeş (2018) investigated the effects of STEM seminars on teachers in North Cyprus and concluded that the STEM seminars had positive effect on teachers’ perceived self-efficacy for mathematical literacy, but did not cause any change in their mathematical thinking ability and use of technology. Margot and Kettler (2019) did a systematic literature review on teachers’ perceptions of STEM integration and education and came to the conclusion that teachers had pedagogical challenges, curriculum challenges, structural challenges, concerns about students, concerns about assessments, and lack of teacher support although they valued STEM education



and needed to be supported in terms of collaboration with peers, quality curriculum, district support, prior experiences, and effective professional development. Although the teachers in this research were competent in their own field knowledge, it was important for them to receive education for the process of carrying on the design of STEM activities. Giamellaro and Siegel (2018) suggested the continuous support system which they defined as “STEM coaching” in the process of reaching outsources and designing STEM activities. The extracted requirements such as mode, forms, topics, and so on for training STEM teachers are precious to universities and other institutions offering professional development courses. They form the basis for further design of computer-supported inquiry-based education to train STEM teachers (Nikolova et al., 2018). Wilson (2011) stated that it is important for the tutors who will provide STEM education to receive practical education on this subject. Based on the Global Education Monitoring Report by the United Nations Educational, Scientific and Cultural Organization (2016), it was stated that supplying STEM teachers with both academic and training qualifications was inevitable to sustain STEM education (cited in Thi To Khuyen et al., 2020).

### Conclusions and Implications

This study revealed that the perceptions of science teachers about E-STEM have been altered after the project. They have gained deeper insight into the “what” and “how” of E-STEM. While science teachers defined STEM as a process of problem-solving before the project, their definitions have become more comprehensive. After the project, they defined STEM as a scientific, creative, and active learning process and as an interdisciplinary teaching approach. Regarding their perceptions about integration in E-STEM before the project, science teachers found that integration of E-STEM disciplines could be necessary. However, after the project, science teachers believed that E-STEM disciplines were required to be integrated. Before the project, science teachers defined entrepreneurship as limited to a few aspects (production, presentation, marketing, and adaptation). But, they defined E-STEM as a process containing the aspects of entrepreneurship (communication, perseverance and determination, self-confidence, motivation, risk-taking, presentation, and marketing) more comprehensively. Regarding perceptions about the properties of the E-STEM process, the science teachers emphasized group work as one of the defining and pleasing aspects of the E-STEM process after the project. Regarding perceptions about the achievements provided by the E-STEM process before the project, science teachers expected from the project to help them learn how to implement the integration of the E-STEM disciplines, transfer what they learn, think multi-dimensionally, and to contribute to their professional development. However, they have learned more than they expected. The science teachers stated that they learned how the E-STEM process was implemented, they learned through trial and error/from mistakes, they learned in a constructivist manner, they could transfer what they learned, they could think more reflectively, empathically, and multi-dimensionally and that the E-STEM process contributed to their professional development.

Looking through the results of the research generally, it has been observed that it is important for the science teachers to receive practical E-STEM education before having teaching experience in terms of their professional development. It may be recommended to perform need analysis on the education to be given to the teachers and to consider the criteria to be taken into account in determining the participants (STEM, entrepreneurship, E-STEM education receiving status, gender, disadvantageous status of the region of office, and so on). It may be recommended to design E-STEM educations to be given in pre-service and in-service education in the form of practical workshops. Those educations may be given by expert personnel with the collaboration of the universities and the Ministry of National Education. It has been observed that combination of STEM implementations with entrepreneurship has generally created positive perceptions for teachers. For this reason, it has been observed that E-STEM is an approach that can be implemented. Developing different education modules for E-STEM implementations and enabling the teachers to have experiences in different scenarios shall contribute to enabling them to bring the disciplines together. After the research, the implementations which the participants perform in their professional life may be monitored and mutual sharing can be provided. Research related to E-STEM designed in different forms of mixed methods or action research can be carried out.



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## Appendix 1

**Figure 2**

*Photographs representative of the stages of the engineering design process*

Stage 1: Define



Stage 2: Learn



Stage 3: Plan



Stage 4: Try



Stage 5: Test



Stage 6: Decide



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