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The Effect of STEM Education on 21st Century Skills: Preservice Science Teachers' Evaluations

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ABSTRACT

The aim of this study is to examine the opinions of the teachers, who participated in STEM education, about the contribution of this education to the development of their 21st century skills. Purposeful sampling was used in this qualitative study, which was conducted as a phenomenology study. In this study, 24 pre-service science teachers for 14 weeks trained STEM activities. The data of the research was collected with a questionnaire with open-ended questions and by conducting semi-structured interviews with a preservice science teacher from each group and analyzed contently and descriptively in terms of 21st century learning environments. Preservice science teachers declared that STEM education developed their learning and innovation skills. Finally, it was ascertained that the STEM education provided to the development of the 21st century skills of preservice science teachers.

Keywords: 21st century skills, STEM education, preservice science teachers

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INTRODUCTION

Rapidly scientific and technological developments in the global world and the technologies that replace manpower are the most important indicators of different professional groups. Hence, countries are necessary to train personnel for a profession that doesn't exist for the time being as well as to make significant arrangements as soon as possible to be able to adapt easily to the changes (Tarhan, 2019). It has now become to produce the information for creating the information society rather than accessing the information (Levy & Mundane, 2006). In other words, it is inevitable to transform the industrial society into an information society (Anderson, 2008; Voogt, 2008). To achieve this, the competencies that individuals need to possess significantly changed, and now, the individuals are expected to master critical thinking, communication as they are expected to be creative, innovative, flexible, compliant, self-confident, and very competent in teamwork (Robinson, 2011). Moreover, these qualities and competencies are often referred to as 21st century skills (Anderson, 2008). These skills constitute the knowledge, skills, and tendencies that citizens need to be able to contribute to the information society (Voogt & Roblin, 2010).

Since it is necessary to fulfill the economic and social demands of the globalized world, there have been many developments in education as well. The role of schools in society has been significantly altered and the need for constant improvement of the quality of education has led to focus on 21st century skills and the actions to take so that the individuals acquire these skills (Bryan, et al. 2015; Brophy, et al., 2008; Morado, Melo & Jarman, 2021; National Research Council [NRC], 2012; Voogt & Robin, 2010; Yang & Baldwin, 2020). This transformation influences many factors including the technological infrastructure and the skills of the teachers. Consequently, it is concluded that 21st century skills should be included in the curriculum of schools (Anderson, 2008). In addition, students and teachers, who are the real stakeholders of the education system, have to be a part of this transformation as well. It is impossible to ignore the competencies, practices of the teachers as well as their beliefs on the education for the realization of this transformation (Trier, 2002). Hence, teachers are expected to have the targeted 21st century skills together with the pedagogical competencies to achieve the goals determined in education (Gordon, et al., 2009; Author, 2017). Thus, it was essential to redefine the qualities and skills of the teachers and students. The effects of the transformation in the global world on education weren't limited to the definition of the 21st century skills in education. If we examine the literature of recent years, we witness the development of pedagogical approaches for training individuals on 21st century skills so that the information society emerges. One of these approaches has been STEM education, which is based on the integration of the disciplines, which have been considerably emphasized and implemented in recent years (Alberta Education, 2007; Beane, 1991; Bybee, 2013; Harrel, 2010; Martín-Páez et al., 2019). Thus, STEM education has become the main focus of 21st century education programs (National Academy of Engineering [NAE] & NRC, 2009; NRC, 2012). Many research indicate that STEM education develops the 21st century skills (Author et al. 2021; Bybee, 2010; Han, Kelley & Knowles, 2021; Idin, 2020, Perignat & Katz-Buonincontro, 2019; Sahin, 2015; Sthele & Burton, 2019; Tytler, 2020). The purposes of STEM education are not exclusively for students but they are also valid for teachers and STEM education aims to increase the knowledge of teachers on the content and pedagogical matter knowledge. It is essential for teachers to learn how to teach the skills that will be acquired through STEM education and what can be done for teaching (Crane, et al., 2003). Accordingly, it is believed that it would be beneficial pedagogically if the teachers, who will provide STEM teaching, experience this education before providing the actual education. Certainly, teachers frequently use their own educational experiences in designing teaching processes (Burns & Sinfield, 2004; Minton, 2005; Tennant, McMullen & Kaczynski, 2009). Hence, it is crucial for teachers to experience this education as a student (Penuel, et al., 2007). Accordingly, hands-on STEM education for the teachers should be prepared for teachers. When all of these factors are considered together, it is crucial to provide pedagogical educations both to teachers so that the teachers acquire the 21st century skills with in-service and preservice education and to the students so that they acquire the 21st century skills. Hence, it is crucial to create an interdisciplinary STEM education framework that analyzes the nature and scope of STEM education integration and the factors related to its scope, purpose, implementation and consequences, and to examine the impact of this education on 21st century skills.

In accordance with this importance, STEM education was conducted to teachers before they began to work in this study and the evaluations of the teachers on the contribution of STEM education on the development of 21st century skills were examined. Consequently, this study aims to examine the evaluations of the teachers, who participated in STEM education, about the contribution of this education on the development of their 21st century skills. In line with the aims of this study, it will be useful to explain the importance of STEM education in the development of 21st century learning skills and learning environment, teachers' skills and 21st century skills:

21st century Learning Skills and Learning Environment

21st century skills in the literature are often called individual qualities, thinking skills, life skills, survival skills, key competencies, necessary skills, employability skills, deep learning skills they are classified in many categories by many different institutions, organizations, and researchers (e.g., Ananiadou & Claro, 2009; Assessment and Teaching of 21 Century Skills [ATCS] Project, 2010; The Partnership for 21st century Learning [p21], 2015;). If we examine the classifications, it is possible to observe that the following skills are the most repeated; creativity, critical thinking, problem-solving, Collaboration, Communication, Information and Communication Technology (ICT) literacy productivity and Social and cultural skills/ citizenship. However, critical thinking and problem-solving skills are included in several different classifications (Ekici, et al, 2017; Voogt & Roblin, 2010). However, they have exclusively included core subjects in some classifications for education and learning purposes. In this study, 21st century skills are studied for educational purposes, since it is necessary to develop some thoughts and insights for assigning the 21st century skills. Hence, the 21st century learning skills are reviewed. It has been emphasized in almost all classification thoughts that the acquisition of skills in 21st century learning environments should be realized around the core and interdisciplinary subjects. Therefore, these issues can be considered a necessity for 21st century learning environments.

In this study, the framework presented in Figure 1 is reviewed, based on the classification created by p21 for learning environments, as emphasized (Ministry of Education of Turkey, 2018), both in many other classifications and the science education program in Turkey.

Figure 1. 21st century learning environment

p21 asserts that the factors mentioned in the framework should be supported by standards, assessments, curriculum and instruction, professional development and learning environments. The fundamental skills that students need to possess to solve complex problems in the global world and to be able to adapt to the change are classified as learning and innovations skills (4C). These skills essentially are as follows; critical thinking and problem solving, creativity and innovation, communication and collaboration. In addition to these skills, it is expected that the individuals possess the following skills as well; decision-making, analytical thinking, entrepreneurship, global world awareness, career awareness, flexibility and adaptability, initiative and self-direction, social and cross-cultural skills, productivity and accountability, leadership and responsibility skills (p21, 2015; Ananiadou & Claro, 2009). It attracts attention that these skills are also included in the classifications in the literature.

- Creativity and innovation skills require that the individual produces new, diverse, and unique ideas based on analytical and scientific knowledge; evaluates the ideas of other people during the production so that the individual contributes to a specific field (Chien & Hui, 2010).

- Critical thinking involves logical thinking and reasoning so that the individual can decide on what to do and what to believe (Evancho, 2000). The problem-solving skill involves applying the solution innovatively by obtaining information for the solution and developing a different perspective (Ulupınar, 1997).

- Communication skill is expressing thoughts orally and in writing for informing other situations, motivating, persuading, etc., listening to others for comprehending the opinions or the situation and doing it effectively (p21, 2015). Collaboration occurs when a person works tolerantly and respectfully with other teams to accomplish a common goal (Kay & Greenhill, 2011; p21, 2015).

- Scientific process skills constitute a set of skills that are adopted for many science disciplines and regarded as a reflection of the accurate behavior of scientists (AAAS, 1990).

- Decision-making is described as a process that requires choosing from alternatives to achieve a specific goal or to achieve the goal (Forman & Selly, 2001).

-Analytical thinking is defined as breaking down complex problems into single and manageable components. If a person is analytical, the person solves the problem with all its dimensions (Panprueksa, 2012).

-Entrepreneurship is defined as launching a new product to the market and the entrepreneur, similarly to the engineering design process, observes the environments, discovers the needs, expresses clearly the ideas, chooses among the ideas, creates a product, tests the products, adapts the product to the environment and manages the marketing process (Deveci & Çepni, 2014).

-Motivation constitutes a force that initiates the behaviors needed for fulfilling a certain need (Walterman, 2005). Individuals are expected to maintain their motivation to continue a job.

When designing 21st century learning environments, activities should be presented to the students so that they can express and experience their ideas and they can produce. There must be people and physical support in place in the environments (p21, 2015, Kay & Greenhill, 2011). Hence, it is possible to allow the students to confront real-life problems so that they find creative solutions after evaluating the ideas of other people. To develop collaboration, and teamwork skills in the process, instructions should encourage teamwork as well.

In the 21st century, it is expected individuals who can think critically, solve problems, communicate effectively and work in collaboration, master the core subjects described as the interdisciplinary themes by the nature of the issues/themes in terms of academic subject knowledge. Each individual must be literate in terms of finance, economics, globalization, profession, entrepreneurship, civil, health, environment, which are the indicators of the development of countries and which master today's world in addition to the subject's literature, foreign language and subjects of science, history, geography, and citizenship, which can be described as the fundamental disciplines (Bransford, Brown & Cocking, 2000; Kay & Greenhill, 2011; p21, 2015). When designing learning environments, building a daily-life context about 21st century subjects and themes can help to explain these subjects.

Hence, in the 21st century's knowledge society, individuals are living in close connection with the information, technology, and media (Bransford et al., 2000; Kay & Greenhill, 2011; p21, 2015, So, it is a necessity for these individuals to be literate of information, media, and technology. Information, media, and technology literate individuals are defined as individuals, who can access information through the media and technology and can analyze and evaluate the information/data they obtain and use the knowledge to solve the problems (Kay & Greenhill, 2011; p21, 2015). To train individuals so that they acquire these skills, technology and media tools should be included in the learning environments and students should be provided the opportunity to use and evaluate these tools and even to create technology and media products.

In today's conditions, knowledge and skills are not exclusively sufficient to maintain life, and it is necessary to have the life and career skills mentioned as "flexibility and adaptability, initiative and self-direction, social and cross-cultural skills, productivity and accountability, leadership and responsible".

While modernizing the learning environments of the 21st century, teachers, as the persons with whom the students interact most after their family and friends (Palfrey & Gasser, 2008), should have the knowledge and skills to successfully manage this learning environment. Thus, the success of various projects related to the establishment of the 21st century learning environment was defined with the fundamental criteria of the adaptation of the pedagogical skills of the learners and teachers (National Center Education Statistics [NCES], 2002). The 21st century learning environment can reach its goal only with the teachers, who know the skills of the students and can guide the teaching process in accordance with these skills (Harris, Mishra & Koehler, 2009; Mazman & Koçak Usluel, 2011). Thus, it is inevitable to need the 21st century teachers, who know the students very well (Melvin, 2011), can create a 21st learning environment for them and guide the students in terms of teaching-learning processes. The 21st century teachers must also be able to adapt to the 21st century conditions, and the teachers should certainly learn the 21st century skills, as the teachers are also the students.

STEM Education and 21st Century Skills

The countries need to train individuals, who can think critically, creatively, and analytically in the 21st century, have high communication skills, can develop solutions to the problems they encounter in daily life, make decisions, conduct studies, interrogate and make conscious decisions in the future career choices (Cantrell & Ewing-Taylor, 2009; Holmes et al., 2018; Kızılay, Yamak & Kavak, 2020; Kier et al., 2014; NAE &NRC, 2009; Tuijl & Molen, 2016). Together with the transformation observed in the world and the structure of the problems, the qualifications required from individuals have changed as the educational policies, approaches, and strategies have been altered as well. In addition, the curricula and teaching, professional development, strategies, and conditions for implementation should be taken into consideration for the implementation of the 21st century skills. This requires an interdisciplinary vision (Vooght & Roblin, 2010). STEM education, which is based on the integration of disciplines particularly for solving the complex problems we encounter in everyday life and for help individuals to acquire the 21st century skills, is specifically recommended for the integration of 21st century skills into teaching, and in recent years, many countries implement this system as one of the most effective educational approaches in the education system (Myers & Berkowicki, 2015; Slavin, 2014).

STEM education signifies a teaching approach based on the integration of the disciplines of science, technology, engineering, and mathematics, aiming to train individuals for 21st century skills so that they can provide solutions to challenges from an interdisciplinary perspective (Bybee, 2000). As it is clear by its definition, STEM aims to develop skills such as scientific process skills, interrogation, critical thinking, and problem-solving skills rather than providing exclusively knowledge (Bender, 2015; Bryan et al. 2015). Comprehending the ways and processes of achieving the integration of the STEM disciplines will, therefore, make it simpler to recognize the role of STEM in helping individuals to acquire these skills.

STEM education process requires the implementation of the scientific method through integrated engineering design to be able to solve authentic, realistic problems, that require the use of science and mathematics, in a meaningful, rich, and social context through integrated engineering design (Bryan & Guzey 2020; Hmelo, Holton & Kolodner, 2000; Lewis, 2006; Mehalik, Doppelt & Schunn, 2008; Myers & Berkowickz, 2015; Roth, 2001). The daily life problems are presented to the students and it is beneficial for the students to search for a solution to these problems so that the students can acquire problem-solving skills and develop other analytical skills. In addition, their interest and understanding of disciplinary concepts of STEM are increased (Gallant, 2011; Yang & Baldwin, 2020). In STEM education, since there is more than one solution to the problems, the students are expected to present more than one solution, coherent with the scientific knowledge and the solution should be different and should have the potential to be developed. The students are also required to evaluate all the solution proposals communicated by everybody (Bozkurt Altan & Hacıoğlu, 2018). Hence, this greatly contributes to the development of the creative thinking and critical thinking skills of the students (Hacıoğlu, 2017; Hacioglu & Gulhan., 2021; Bozkurt Altan & Tan, 2020; Wan, So & Hui 2021,).

Although there are many methods to integrate STEM disciplines (Bybee, 2000), design-based engineering or technology applications are recommended (Leonard, 2004; Wendell, 2008; Mehalik, et al., 2008). In design-based education or STEM education, engineering or technology design process is required to be realized and there is a need to create a product (Bender, 2015; Felix, 2016; Fortus, 2003; Fortus, et al., 2004; Fortus, et al, 2005; Wendell, 2008).

While this process improves the knowledge of students on science, it also helps to develop the design skills of the students (Kolodner, 2002; Leonard, 2004; Yang & Baldwin, 2020). This process is highly based on teamwork and collaboration (Myers & Berkowickz, 2015). As this is closely related to the modern working environment, (Bender, 2015), it is highly influential in the increased level of self-confidence of 21st century individuals and the developed communication skills (Smith & Karr-Kidwell, 2000; Kolodner, et al., 1998). In addition, during the process, it is expected that the decision-making skills of the students will be improved since they will be evaluating the suggestions on the problem and creating the products (Bozkurt, 2014). Furthermore, the integration of technology and mathematics disciplines aims to develop technology literacy, algorithmic thinking, and thinking skills based on calculations (Çorlu, 2017).

To obtain information particularly about the science discipline, it is essential to include the interrogation together with the design processes for the process of solving problems (Wendell, 2008; NRC, 2012). This greatly contributes to the development of the science process skills of the teachers (Bozkurt, 2014).

METHOD

This research, which investigates the effect of STEM education on preservice science teachers' 21st century skills as their evaluations, is a qualitative phenomenology study. It is discussed in phenomenology studies that the participants feel about their experiences, their perceptions, and thoughts and how they structured them and what kind of a state of consciousness they created in themselves (Van Manen, 2007). This research includes the opinions of preservice science teachers, taking STEM-based science teaching laboratory courses, about the contribution of STEM education in the acquisition of the 21st century skills.

Participants

In this study, the non-probabilistic (purposeful) sampling technique was used because the STEM education experiences of preservice science teachers were important. The study group consists of 24 preservice science teachers (19 female and 5 male teacher candidates) that they are a student in third-grade in an education faculty of a state university in 2017-2018. The study group voluntarily participated in the study. In this study, the participants were mentioned by coding as PST1 (preservice science teacher 1), PST2, …., PST24.

STEM Education Experiences and 21st century skills' knowledge of Preservice Science Teachers

The preservice science teachers who participated in this study did not have sufficient knowledge and experience in STEM education, while they had previously taken courses about 21st century skills and have knowledge about them. To evaluate STEM education in terms of 21st century skills, it is important that they had experience about STEM education. For this reason, it was ensured that they experience via STEM activities. These activities were previously developed, applied and validated by the author for another study (Hacıoğlu, 2017) in accordance with engineering design-based science education that manages the engineering design process. In this study, the activities were applied for 4 hours each week for 14 weeks during the Science Education and Laboratory Implementations II course (September 2017- February 2018) with the participants different from participants in the study of Hacıoğlu (2017). In the preparation of the learning environment and during the process, the points emphasized in the theoretical framework for the development of the 21st century skills were taken into consideration. In this study, preservice science teachers carried out three STEM units include three grand design challenges ***(designing a straightener for clothes, designing an environment friendly vehicle, designing a sanitizer).*** Each of the grand design challenges consists of mini designs and mini research that will enable the preservice science teachers to acquire the knowledge and skills needed to achieve a considerably great design and complete these great design challenges. In this research, preservice science teachers carried out 8 mini research and 7 mini design challenges regarding 3 grand design challenges. In the whole process, the engineering design process and the research inquiry process were carried out together and repeatedly. For each STEM units, first, the problem statement was given for each grand design challenge and it is explained. After determining the criteria and limitations of the design challenge, searched the needs of problems and mini designs and mini research were carried out, where they will gain the necessary knowledge and skills to develop possible solutions. The engineering design process for each mini design, the inquiry process for each mini research were carried out and over again. Thanks to the knowledge and skills obtained as a result of mini research and mini designs, the participants suggested solutions for the grand design challenge, evaluated the solutions in the context of criteria and limitations, selected the best solution, designed a prototype, tested, revised and presented the best solution. Eventually, they completed their grand design challenge. It took a minimum of two weeks and a maximum of 4 weeks to complete each major design task. Detailed information about this activity can be found in the study of Hacıoğlu (2017).

Research Instruments and Procedures

The data of the research was collected with a questionnaire with open-ended questions and by conducting semi-structured interviews with a student from each group. In the questionnaire with open-ended questions, preservice science teachers were asked to share their opinions about STEM education's impact on the development of 21st century skills as *"Do you think STEM education has an impact on the development of your/learners' 21st century skills? If you think that STEM education effects learners' 21st century skill development, please indicate which skill it has. Explain your opinion in detail with its reasons. "* . To support the data obtained from open-ended questions, semi-structured interviews were conducted with a total of five preservice science teachers (PST1, PST2, PST3, PST4, and PST5).

Data Analysis

In this study, the steps of qualitative data analysis were followed; content and descriptive analyses were conducted. First, the data obtained from open-ended questions were coded for content analyses and their frequencies are determined. Then, in the process of creating themes by categorizing the generated codes, it was seen that the pre-service teachers did not only evaluate the process in terms of skill development but also in terms of the 21st century learning environment. So, the codes about the same subject were categorized in terms of 21st century learning environments in Figure1. To support the data obtained from open-ended questions and ensure reliability, the data obtained from the semi-structured interviews were analyzed descriptively in terms of 21st century learning environments. For the validity and reliability of data analysis, the researcher analyzed and compared the same data at different times. In this study, quotes of the opinions shared by the participants are given to assure the validity of the results.

The findings obtained from open-ended questions are given by using separate radar diagrams for each theme to be more detailed and descriptive, rather than tabulated. The explanations of the teacher candidates (the quotes) in the relevant category and the findings obtained from semi-structured interviews were interpreted under the relevant diagram. The quotes from interviews were given frequently because they are more detailed from the open-ended questions.

FINDINGS

The findings obtained from the answers of the preservice science teachers to the open-ended question related were categorized according to the dimensions of the 21st century learning framework.

The codes and frequencies for the theme of "Learning and innovations skills" are presented in Figure 2 in a radar diagram.

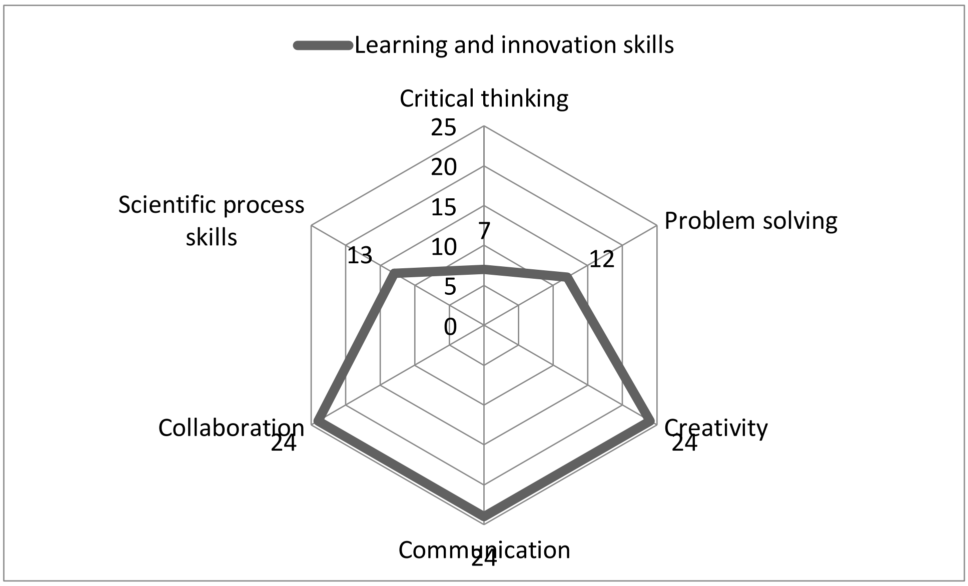

Figure 2. Findings in the theme of "Learning and innovations skills"

Examining answers of prospective science teachers related to themes of "Learning and innovations skills" (Figure 2), it is seen that they declared that STEM education contributed to the development of learning and innovation skills. However, all preservice science teachers stated that exclusively STEM education developed their skills of creativity, communication, and collaboration among the learning and innovation skills. When the explanations of the

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preservice science teacher are considered; they have explained the development of their creativity by the fact that they have offered many solutions for solving a problem encountered in daily life. They have also mentioned that their ability to work a team and collaboration has been increased and since they conducted some mini research and they needed the scientific information for solving the problems, this education program contributed to the development of their problem solving, critical thinking and scientific process skills.

PST1 explained that STEM education provides the development of creative thinking skills: *"... We had to use our creativity to create a solution and we have realized that we couldn't use the same material for everything and we have realized that we need to produce. We used and developed our creativity while testing our solution proposal and redesigning the design we have previously created...*

and added that STEM education needed to use collaboration and communications skills, so it provides the development of these skills:

"...Hence, communication was the most valuable skill. In the end, we were working as a group, we need to discuss, communicate and work together to make decisions and optimize our solution. As we were working as a group, I think that our collaboration skills have improved..."

Like PST1, PST5 stated also that STEM education provides the development of collaboration and communications skills. And also, he/she emphasized that it provides the development of critical thinking skills:

"In some groups, even people who don't have a friendly relationship learned to work as a team for the sake of common purpose. Therefore, we have learned how to express ourselves, to listen to each other, to comprehend what we mean... ".

On the other hand, PST4 explained the development of science process skills by the fact they have used the inquiry skills when conducting a study:

"...We have obtained necessary information by conducting experiments for solving the problem. I think this STEM education program contributed to my development in terms of number-space relationship, observation, the establishment of a number-space relationship, deduction, and comparison. Because we have used them in the process and we have realized our designs with the skills we have obtained...".

PST 13 explained the development of problem-solving skills by the fact the design process run to challenge of real-world problem:

"...In all units, the process started with a real-life problem and we designed to solve this problem. The more solutions we offer, the more successful we have been. That's why the process improved our problem-solving skills as creativity...".

The codes and frequencies for the theme of “Life and career skills” are presented in Figure 3 in a radar diagram.

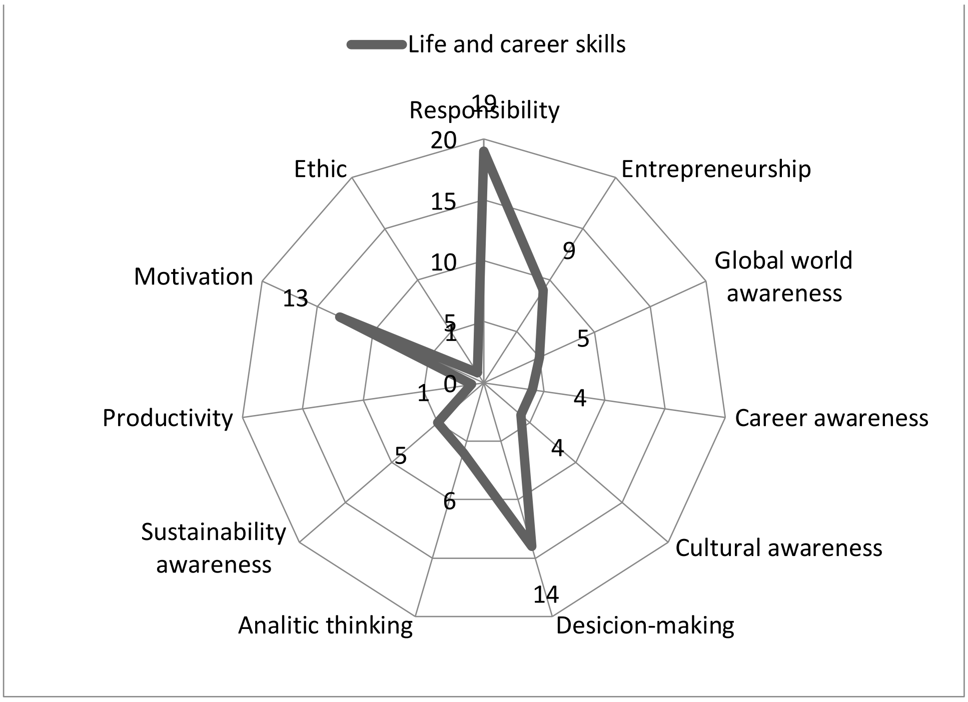

Figure 3. Findings in the theme of "Life and career skills"

Examining answers of prospective science teachers related to themes of "Life and career skills" (Figure 3), it is seen that they stated frequently that STEM education provides responsibility, decision making, motivation, and entrepreneurship skills. They have explained this by the fact that they have strived seriously to find a solution to the problem or to complete a design challenge or choose the best solution among the solutions or options.

PST16 stated their opinion about the effect of STEM education on responsibility:

".... The process begins with a problem-solving task. Therefore, students need to be active while solving problems, designing experiments, generating solutions, and designing the prototype. Each of these requires him to take responsibility and fulfill his task within the group. Therefore, a sense of responsibility develops also... "

Preservice science teachers stated their opinion about the effect of STEM education on decision-making skills by associating with the process. PST1 stated:

"...We had to use our decision-making skills when deciding on the best solution.... " and PST7 stated:

"... To be successful in solving the problem, it is important to choose one of the solutions and to decide how and what material we will use in the realization of the prototype. For this, both critical thinking skills and decision-making skills are developed by taking into account the opinions of others... "

PST5 stated during the interviews about motivation:

"... We have designed during the process, and completing a design has considerably increased our motivation. Maybe we were bored, sometimes because we were impatient, but we were satisfied with the designs that we have created, and we were happy and motivated, and we wanted to see the designs our friends created. At first, we wondered what we could do, whether we could truly create a successful design. Now we are investigating everything, outside of the course as well. ... "

and added her/his opinion related to the effect of STEM education on career awareness, unlike most other prospective science teachers who address career awareness unlike most prospective science teachers:

"... I can say our general interest in life has been improved. In fact, I can say that my career awareness has also increased. I apprehended the relationship between professions and disciplines. It also contributed to my career since I was going to use them as a teacher..."

Like some preservice science teachers, PST 22 stated that STEM education provides the development of entrepreneurship of learners:

"... It also improves entrepreneurship skills. For example; When I am a teacher, I can make different designs for my students and patents them..."

Preservice science teachers mentioned that STEM education affects sustainability awareness. PST18 stated explained:

"... In fact, we paid attention to choosing materials that are both environmentally friendly and can be used for a long time, with low cost in all design tasks. This improves the awareness on sustainability. For example, the problem with the task of designing air and water-powered vehicles served this as well ..."

Some preservice teachers stated that STEM education develops also analytical thinking skills for example PST21 explained:

"... We determined research questions to solve all problems - grand design challenges. We gradually obtained the necessary information to solve the problem thanks to mini design and mini research, and discussed how each would help solve the problem. So we tried to solve the problem piece by piece. This improves analytical thinking skills in my opinion... "

Only PST19 emphasized the ethical dimension of the process and explained it by associating it with its effect on cultural awareness:

"... While we were solving the problems, we realized that the ethical dimension is also a criterion or even a limitation. For example, in the disinfectant design process, we had to make an ethical decision, taking into account the usefulness and the harmful feature. We also took care to use substances that are compatible with religious views of societies.... " Only PST6 mentioned the effect of STEM education on productivity:

"... I realized that the more solutions we offer for each design, the more successful we will be in solving the problem. This improves our productivity with creativity. If STEM education is carried out, we get used to productive thinking.... ".

The codes and frequencies for the theme "Core subjects for science course" are presented in Figure 4 in a radar diagram.

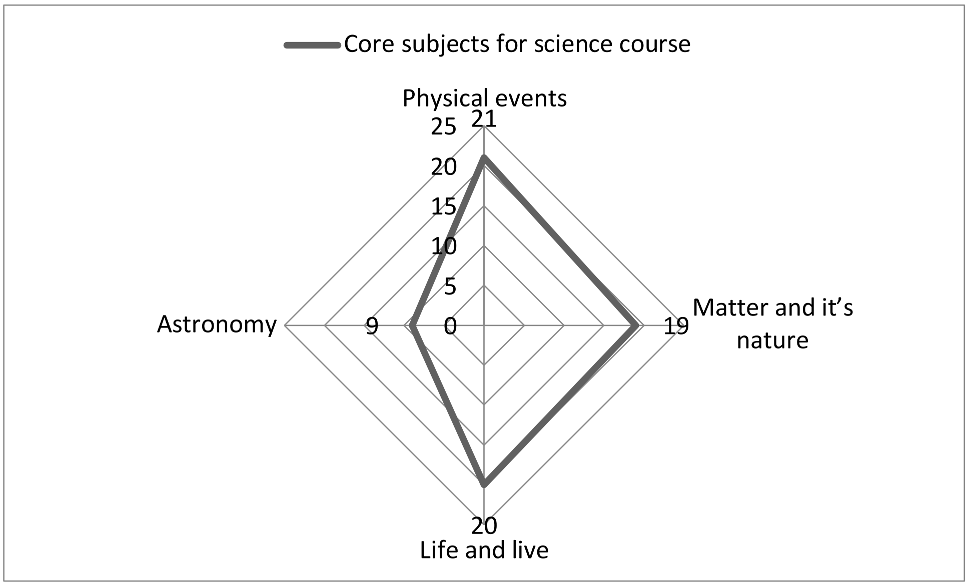

Figure 4. Findings in the theme of "Core subjects for science course"

Examining answers of prospective science teachers related to "Core subjects for science course" (Figure 4), it is seen that all preservice science teachers declared that STEM education provides the teaching of science subjects related to 'physical events', 'life and live', 'matter and its' nature' and/or 'astronomy' thanks to STEM education. They explained this situation related to their STEM education experiences. They frequently stated that they learned the science concept and subjects thanks to the implemented activities. For example, PST16 stated that STEM education affects positively learning of knowledge about physical events: *"...I think that STEM activities are effective in understanding physical phenomena since they are mostly related to physics subjects. For example, we learned about heat, heat, heat and electricity transmission and insulation while designing irons. If we had designed a vacuum cleaner, we could learn about electricity, pressure, and sound transmission, and we could develop an understanding of these concepts. But I think it will improve knowledge in all science subjects. The research problems we use in our designs are aimed at improving the information stage...".*

PST2 explained their opinions by giving example related to core subjects of 'matters and its nature':

"...We have realized that we need to use science subjects for solving daily life problems and hence, our awareness about these issues has been significantly increased. For instance, I have realized that we had to take into account the characteristics of a substance when using the substance in a design or a product. We have developed our knowledge, particularly when

combining materials having different properties. This is valid for all science subjects according to the discipline knowledge required to solve the problem we encounter…".

PST 12 explained also their opinions by giving example related to core subjects of 'life and live':

"…For example, in the disinfectant design unit, we investigated the classification of living things, which creatures are microbes and cause diseases, and how their structure, living conditions are reproductive, growth and development. Then, we designed our disinfectant by thinking about how to eliminate these conditions…".

However, it is noteworthy that they least mentioned the contribution of STEM education to the development of knowledge about astronomy that isn't context or content in the implemented activities. PST 24 explained about it:

"We did not organize activities in STEM activities in the field of world and universe learning, but I think STEM can increase knowledge and skills in all learning areas. For example, if we or students are given a problem or a design challenge in the context of world and space, we need to obtain space information to solve it…".

The codes and frequencies for the theme "Interdisciplinary themes" are presented in Figure 5 in a radar diagram.

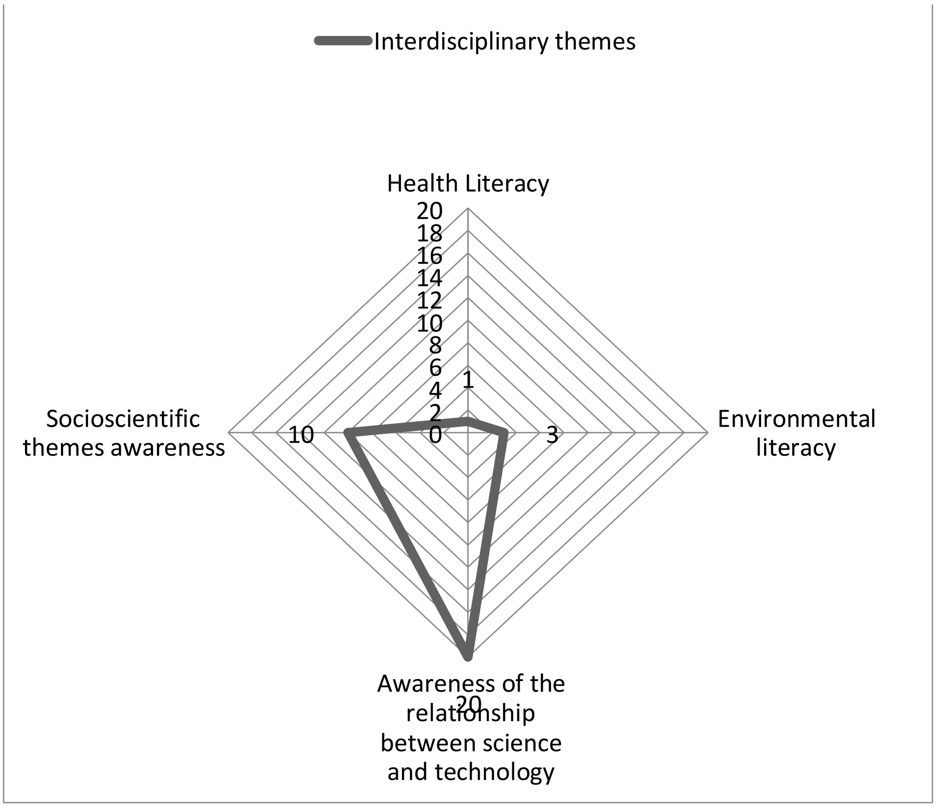

Figure 5. Findings in the theme of "Interdisciplinary themes"

Examining answers of prospective science teachers related to themes of "Interdisciplinary themes" (Figure 5), it is seen that some preservice science teachers declared frequently that they solve problems with interdisciplinary themes knowledge, so they needed and learned to knowledge related to disciplinary themes thanks to STEM education. Most of them stated that it provides awareness of socio-scientific themes -and especially- awareness of the relationship between science and technology. For example, PST3 shared her/his opinion during the interview as well and stated:

"Students can learn about professions with such practices. I raised awareness of the environment and sustainable development in terms of product design. I have said so many times. While we were learning science, we are using the information but we are not producing anything. From this perspective, we have learned to use the relationship between science and technology. The problem used in STEM education is generally a problem that we encounter every day in life. These problems are both scientific issues and social issues. This education allows finding a solution to socio-scientific issues or at least having the knowledge. Even if you talk about these issues, your awareness is raised."

Some preservice teachers explain the process related to the context of the problem situations like PST22 and mentioned that STEM education develops environmental literacy. For example, PST17 stated:

"...The disinfectant we will use also had a criterion of not harming the environment. The purpose of the vehicle design that works with air and water was to design a vehicle that does not harm the environment. I think that the information and process -we obtained while solving these design tasks- affected positively our attitude and behavior towards the environment. Thanks to STEM activities to be carried out in the context of similar environmental problems, students' environmental behaviors can also change positively....".

Only PST22 mentioned that STEM education affected his/her health literacy related to the context of design problems situation as PST:

"...We can say that our awareness about health has increased and even our literacy has increased. We designed a disinfectant to find a solution to a health problem. But we did not only use scientific knowledge to solve this problem. We felt the need to read articles about health. We read and used the knowledge in our disinfectant design...".

RESULTS AND DISCUSSION

Preservice science teachers stated that STEM education considerably contributed to the development of 21st century knowledge and skills. In fact, STEM education involves combining at least two of the STEM fields, together with the use of knowledge, skills, and beliefs of the individual in these fields (Çorlu, Capraro & Capraro, 2014).

Preservice science teachers mentioned that STEM education helped them to develop their scientific knowledge that is needed for solving the problem given in the process and they have also stated that their awareness on interdisciplinary themes has been increased. Acknowledging that it will be complicated to realize designs without science content knowledge (NRC, 2012).

This is an expected result since the participants have conducted mini research preservice science teachers also expressed that STEM education does not only increase disciplinary learning but also improves their awareness of socio-scientific issues as well (Abdullah, Halim & Zakaria, 2014; Crismond, 2001, Cotabish, et al., 2013; Martín-Páez et al. 2019; Struyf et al. 2019). We assume that it is related to the fact that the daily life problems used in the process involve much interdisciplinary information and socio-scientific issues such as cancer, climate change, and energy need (Çorlu, 2017). Consistent with this assumption, prospective science teachers think that STEM education will increase their awareness of the relationship between science and technology and socio-scientific issues. Although not the majority, they think that it will raise awareness about health and the environment in the context of the problem issue. They stated that core concepts have also developed while finding solutions to these interdisciplinary issues. As the developing core concept, 'physical events', 'life and live', 'matter and its nature' and 'astronomy' respectively. When the activities related to STEM were examined, it was seen that there were many physical events and activities. However, contrary to the opinions of the teacher candidates, it was stated that the activities in life science and astronomy were limited (Hacıoğlu, 2017; Roehrig, et al., 2021). It can be suggested to increase the STEM activities and applications related to these core concepts to support these opinions of teacher candidates.

Preservice science teachers stated that STEM education helped them to develop creativity, communication, collaboration, critical thinking, and problem-solving skills, which are mentioned as fundamental skills. In addition, they have mentioned that the process contributed to the development of responsibility, decision-making, entrepreneurship, analytical thinking, global world awareness, sustainability awareness, career awareness, cultural awareness, and productivity skills among the life and career skills. Preservice science teachers have also expressed their ideas as they have supported the related literature.

Preservice science teachers have regularly stated that STEM education develops the scientific process skills among the 21st century skills required for science learning as Meyrick (2011), Park et al. (2011) and Parno, et al. (2018, 2020). They declared that the development of these skills was ensured by the small research and research/experiments they have realized for solving the problem. As the experience of teachers or preservice teachers in terms of STEMoriented implementation increases, the skills develop, as many researchers stated (Bozkurt, 2014). Many researchers, by relating the results to the nature of the engineering design process, have stated that STEM education supported the development of critical thinking and creativity (Hacıoğlu, 2017; Kim & Choi, 2012; Kim, Ko, Han & Hong, 2014; Kwon, Nam & Lee, 2012), scientific process skills and decision-making skills (Bozkurt, 2014;). In design-based STEM education, participants strive to solve a problem while trying to complete a design challenge (Fortus, et al., 2004; Lin et al., 2021; Parno et al., 2019). To achieve this, individuals need to offer more than one solution (Silk & Schunn, 2008), so that, as the preservice science teachers indicate, it is expected to use and develop problem-solving and creative thinking skills (Hagay & Baram-Tsabari, 2015; Mentzer, 2011). Although in this study preservice science teachers don't emphasize the effect of STEM education on productive thinking skills, detailed studies in the literature that STEM education improves creativity skills reveal that STEM education also improves students' imagination and productive thinking skills as they design (Aranda et al., 2020; Lin et al, 2021; Guzey & Jung, 2021). When preservice science teachers emphasized their critical thinking, collaboration, and communication skills have been improved when they are elaborating the opinions of other people and work in a group, this opinion supports the views of Kolodner, et al. (1998). Furthermore, their research proved that interdisciplinary STEM education has developed the scientific process (Sullivan, 2008), decision-making skills (Bozkurt, 2014), as well as critical thinking and problem-solving skills (Bybee, 2010). Some research (Baran et al. 2019; Lin et el., 2021; Guzey et al., 2016; Guzey & Jung, 2021) stated that STEM teachers believe that students who attend STEM education might become more interested in STEM fields.

Preservice science teachers stated that they were striving to perform their design challenges and their efforts to find a solution to the problem, and hence their skills of being responsible and motivated have been increased during STEM education. Supporting these views of teachers, Moore (2004) states that finding solutions to authentic engineering problems in the Stem education process increases students' motivation to solve real-life problems. Preservice teachers explained also that STEM education provides entrepreneurship skills. Since complex interdisciplinary problems are solved in STEM education, entrepreneurship skill is also important and can develop (Flanagan 2020). In addition, the fact that they are aware of the fact that they can produce since they can create a design also indicates that STEM education contributes to the skills expected from an individual living in the 21st century (Robinson, 2003). Certainly, one of the common aims of STEM education is to increase the interest in STEM fields, but also to develop the skills that individuals should possess in daily life and career processes (NRC, 2012; Lin et al., 2018; Lin et al., 2021).

Since preservice science teachers have conducted research and implemented practices in interdisciplinary fields during the process, they have mentioned that their knowledge about other professions, activities, the career fields has been increased. Undoubtedly, one of the aims of STEM education is to increase the interest in STEM areas and to increase the awareness of individuals in these fields by creating a career awareness (NRC, 2012; Accelerating Strategies for Practical Innovation and Research in Economic Strengthening [ASPIRES], 2013; Park & Lee, 2014). In fact, studies have revealed that STEM education increases the perception and awareness of the individual's career (Baran, et al., 2016; Bishop, 2015; Guzey, Harwell, Moore, 2014; Heaverlo, 2011; Kutch, 2011; Holmes et al., 2018; Wang, Ye & Degol, 2017; Wayne Long, 2012). Thinking that the students do not know enough about the engineering profession (Gibbons, Hirsch, Kimmel, Rockland & Bloom, 2004; Hirsch, Capinelli, Kimmel, Rockland & Bloom, 2007; Spencer, 2011), it is hopeful to think the awareness of the teachers that will teach these issues to the students has been increased.

Remarkably, the preservice science teachers did not express their opinions on the development of information, media and technology skills among the 21st century skills. It can be considered that this is related that STEM education was based on engineering design. As the preservice science teachers focused on the integration of engineering discipline, they may ignore the literacy about other disciplines. Although this result constitutes a limitation of the research, it is limited to the practices implemented and the opinions of the participants. Finally, it was ascertained that the STEM education provided to the development of the 21st century skills of preservice science teachers.

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