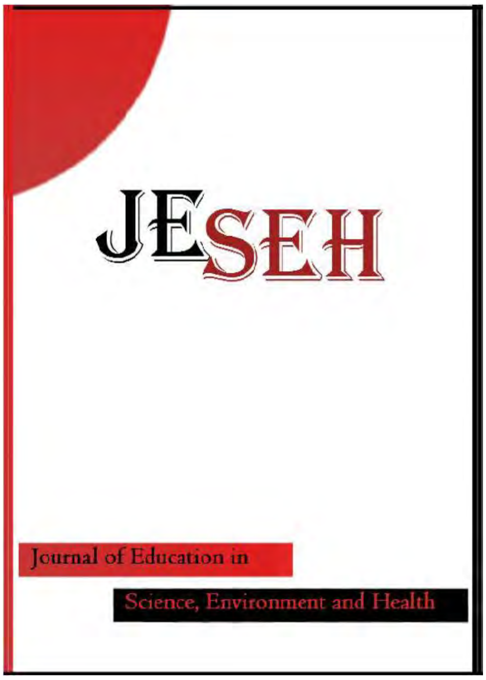

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Abstract

In this research it is aimed to examine the effects of STEM-based activities on pre-service primary school teachers' scientific inquiry skills, conducted in a science education course of third year undergraduate students. A mixed research method, combining pretest posttest single group design and semi-structured interviews guided the study. Participants of the study consist of 47 pre-service primary school teachers in a state university. The activities implemented with third grade pre-service primary school teachers for ten weeks/thirty course hours. "Views About Scientific Inquiry" scale which was developed and translated into Turkish was used as data collection tool. Based on the eight aspects of science standards, a STEM activity plan was created for each of these dimensions in terms of science, mathematics, engineering and technology achievements. Test as pre and post-test are analyzed statically and for the normally distributed data of VASI, the dependent samples t-test was applied. The dependent sample t-test was used to determine whether there was a significant difference between the pre-test and post-test scores after the scientific method-based STEM applications. Semi-structured interviews were performed to support quantitative data and analyzed descriptively. Results of the study showed that at the beginning of the research, the scientific inquiry skills and views of the pre-service primary teachers were inadequate. Additionally, there is a significant difference on scientific inquiry skills and views of the study group, participating in the STEM-based science activities, after STEM applications and activities within the course. It can be concluded that STEM based activities enhance scientific inquiry understandings and skills of pre-service primary school teachers.

Introduction

With the globalization economic success in an integrated world, technological development, defense industry leadership in the fields of wins. With these developments in the world countries and with the scarcity of resources the innovation race between countries raises. The importance of science and mathematics education is increasing day by day, as technology and knowledge production accelerate. In addition, technology and engineering fields, where theoretical knowledge in the fields of science and mathematics are transformed into practice in daily life, offer different solutions to people's current problems (Yamak et al., 2014). Countries and quality education disseminating fairly to all segments of society competition, as well as increasing the quality of education made different plans for different programs they have implemented. By report of the European Union in 2007 named "Science Education Now: Europe's Renewed Pedagogy for the Future" it is highlighted that (Rocard et al., 2007) science and technology education is alarming and especially young people in science, technology and mathematics significant interest in the lack of effective action plans, in the case of Europe's long-term innovative capacity will be significantly reduced. In the related report, not only science and technology education in schools, but also society's survival and adapted to the scientific and technological atmosphere information use skills to help great emphasis was placed on.

Experts who prepared the report presented some important suggestions for questioning in the report. Accordingly, the transformation of school science teaching pedagogy from classical methods to inquiry-based science teaching approach will increase students' interest in science. Asking various questions is the basis of the inquiry-based learning and teaching process. These questions open new doors to the student's imagination. In this process, students learn science concepts and scientific research process by gaining high-level cognitive skills. According to Evans (2001), inquiry-based teaching in science; It is "the student's asking questions, conducting research on the questions asked and collecting data, interpreting the findings and coming to a conclusion and thinking versatile, critically and creatively". A strong awareness of scientific inquiry has positive effects on both student achievement and attitudes and values towards mathematics and science (Anderson, 2002). Therefore, scientific inquiry is widely accepted as an effective teaching practice for scientific teaching in today's classrooms. However, teachers need to be successful in guiding their students to construct knowledge like scientists (National Research Council, 1996, 2000). In order to apply inquiry-based science teaching, teachers should have the equipment required by this method. Because teachers who do not have the equipment and training required for inquiry-based teaching will not be able to help students to construct science concepts in their minds and instruction will not be carried out in a healthy way because they cannot follow a suitable path for this construction process (Sandoval et al., 2002).Scientific inquiry-based classroom activities help students develop critical thinking skills and enable them to construct knowledge like a scientist (Schneider et al., 2002). Inquiry-based science education and renewed school science teaching will create opportunities for cooperation between stakeholders in formal and informal fields. In addition, it is thought that teachers are the most important people in the renewal of science education. Teachers' motivation should be increased. After this report, the European Union made calls for projects under the field of science and society for the renewal of science and technology education throughout Europe and the implementation of inquiry-based science education specified in the report, and gave researchers the opportunity to develop cooperative projects across Europe.

It is predicted that as a result of these processes, more scientific and technologically literate individuals will be raised in the society, and in this way, a rich dialogue and active cooperation can be established between science and society. In addition, the incredibly rapid changes and developments in science and technology, the effects of these processes on society are important. It is necessary to integrate the interests and value structures of citizens by bringing the society together with science, innovations and policies and activities in this direction. Citizens should be made acquainted with science through formal and informal science education (science centers and other channels). It is necessary to provide more active access to scientific and technological projects for society and to increase the usability of their results. The National Science Teaching Association (NSTA, 2004) states that learning science and engineering practices in the early years can increase children's curiosity and fun in exploring the world around them and lay the foundation for the advancement of science learning in all these environments. Moreover, current research shows that children have the capacity to construct conceptual learning and the ability to use reasoning and inquiry practices (NRC, 2012). It is known that the science education programs of many countries include different approaches. Among these, 21st century skills are included in education programs of countries such as Australia, Finland, Canada, Italy, Norway, Belgium, France, New Zealand, England and Ireland.

21st century skills express the characteristics that enable individuals to be good and qualified citizens in this century's information society (Ananiadou & Claro, 2009). In addition, the special skills used represent a cognitive, behavioral and affective development not only in school life, but beyond school. This comprehensive definition of skills makes it possible to take into account the diversity of tendencies, knowledge and abilities that a student must possess to demonstrate a particular form of expertise (Lamb et al., 2017, pp. 11, 12). Howard Gardner states that our children should be equipped with the knowledge and skills to do things that "machines cannot do" from now on. Gardner's warning is actually "21. century skills", because the next decade will witness the end of the industrial era that took shape in the last 200 years and the beginning of the "individual industry" era (Aydeniz et al., 2015). In this transformation process, skills such as "creativity", "critical thinking", "problem solving", "cooperation", which have been sufficient for centuries in only a very small part of societies, will be a kind of "universal literacy" in order to survive in the 21st century. It does not seem possible for children to acquire skills such as creativity, critical thinking, problem solving and collaborative work with the classical education approach in the industrial era format.

The scientific inquiry process is also a problem-solving process based on individuals' ability to design, construct, and think. It can also integrate technological/engineering problem solving and/or mathematical problem-solving skills into this process (Lee et al., 2014). Students will be able to evaluate design systems best in real life and design in design. Also, transportation vehicles, teaching STEM disciplines education courses and teachings. The current educational approach; teaches science, mathematics and technology content to students in isolation from each other (Ültay & Ültay, 2020). However, it has become the most important vision of all countries to raise individuals equipped with 21st century skills and according to the modern education approach. Students who receive a qualified science education adapted to 21st century skills have a full, accurate and working understanding of the nature of science (NSTA, 2000). Teachers and educators should build on the opportunities that already exist in school programs and teaching practices to support 21st century skills (Bybee 2010a, 2010b). Ongoing professional development opportunities and effective pre-service and initial programs for educators should support the integration of 21st century skills into classroom teaching (Windschitl, 2009). Also, a wide range of technologies serve as tools to engage children with real-world problem solving, conceptual development, and critical thinking. Considering that the integration of science and technology in different disciplines affects students' attitudes towards science positively (Ürey & Çepni, 2014), the subjects should be taught in an interdisciplinary manner. At the same time, they can solve daily life problems like engineers by using their systematic thinking and analytical thinking skills in STEM activities. Therefore, these activities offer students the opportunity to develop both inquiring scientific skills and engineering process skills at the same time (Locke, 2009). At this point, of course, in order to raise such individuals, it is necessary to train teachers who can achieve this integration. An integrated and content rich education program with STEM activities can serve a crucial role for teacher training from this point. Within the scope of these perceptions, this research aims at determining the effect of STEM education on the preservice primary school teacher's scientific inquiry skills. Within the scope of this, answers to these research questions have been sought; (1) What are the level and views of preservice primary teachers about scientific inquiry skills before taking any training about STEM education? (2) Does STEM education affect development of the preservice primary teachers' scientific inquiry skills?

Method

Within the purpose of this study explanatory research design is preferred. Explanatory research designs are conducted to explore and search through a problem or situation to provide insights and understanding. Also, partially mixed concurrent dominant status method was used in order to set research design. The purpose of this method is to simultaneously collect both quantitative and qualitative data, and also analyze and compare the results (Creswell, 2013).

In the quantitative part of the research, the single group pre-test and post-test experimental design and in the qualitative part of the research, semi-structured interviews were used. In general, mixed methods research represents research that involves collecting, analyzing, and interpreting quantitative and qualitative data in a single study or in a series of studies that investigate the same underlying phenomenon. A partially mixed concurrent dominant status design involves conducting a study with two phases that occur sequentially, such that either the quantitative or qualitative phase has the greater emphasis (Leech & Onwuegbuzie, 2009).

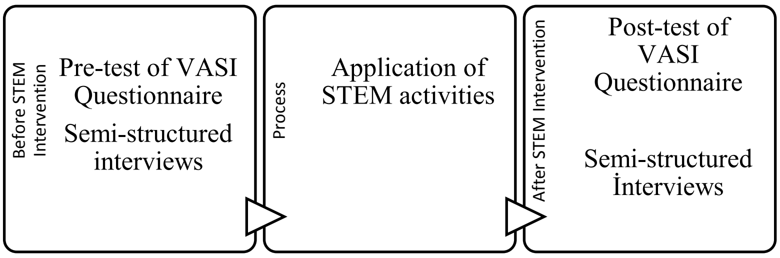


Figure 1. Research design of the study

Triangulation was administered with the intention of supporting both qualitative and quantitative data and improving the trustworthiness of the study. It refers to the use of multiple methods or data sources in qualitative research to develop a comprehensive understanding of phenomena (Bogdan & Biklen,2006). Triangulation also has been viewed as a qualitative research strategy to test validity through the convergence of information from different sources (Patton, 2002; Yıldırım & Şimşek, 2008). In addition to this, another researcher analyzed and evaluated the data independently to enhance its credibility and thus expert opinion was obtained in order to increase the trustworthiness of data analysis.

Participants

The participants of the study were pre-service teachers who were third grade students in primary school teacher education program in a university located at the north part of Turkey. The participants consisted of 47 preservice primary school teachers studying in a state university in Giresun province in 2018-2019 academic year. Convenient sampling was used for the selection of the population. Convenient sampling, one of the purposive sampling methods, may be used for in general the goal of deliberately selecting units that are best suited to enable researchers to address their research questions (Frey, 2018) and also ideal for research design. The study group has not been exposed to STEM education before.

Research Process

The researcher guided pre-service primary school teachers in this process and to perform the STEM activities, they did follow the scientific inquiry process in groups. In the scientific inquiry process here, the stages of the statement of problem, obtaining information, developing ideas, product development, testing, sharing and reflecting, evaluation were followed. At the beginning of the study, STEM based activities in the literature were examined in depth to prepare activity program for preservice primary school teachers. This search is focused to the STEM activities related to the STEM education which would be implemented for the acquisitions of the subjects and issues defined in National Science Standards.

The American National Standards for Science Education (NRC, 1996) recommend eight core content standards for childhood science education. As mentioned before, the eight aspects of science standards are: (1) Life sciences, (2) Physical sciences, (3) Earth and space sciences, (4) Matter Science, (5) Unifying Concepts and Processes in Science, (6) Personal and Social Science, (7) Science and technology and (8) History of science. A STEM activity plan was created for each of these dimensions; science, mathematics, engineering and technology achievements of these activities were determined. Some basic topics such as "heat loss", "artificial intelligence", "light pollution", "space technologies", which can be studied at primary school level within the framework of science standards, are at the center. With the STEM education to be given in this research plan, it is aimed to provide preservice teachers with the ability to solve problems, develop projects and turn their ideas into production. In this way, it is intended to contribute to equipping the children they will teach and raise with these skills in the future. Additionally, developing inquiry-related STEM learning could improve the positive attitude of educators towards the teaching and learning of STEM content (DeCoito & Richardson, 2018).

The researcher guided the participants during the implementation of the measurement tool and the implementation of the activities. Before the implementation of the STEM Activities, the VASI Form, which provides the quantitative data of the research, was applied to the students as a pre-test in a class hour. Afterwards, since the students did not have any experience with STEM education, information about the process, responsibilities and how the course would be conducted was explained to the students. The implementation phase of the research was carried out in the form of group work.

The groups were organized by the researcher to consist of at least four and at most five people in order to ensure the efficiency of the group members and the healthy outcome of the activities to be done. For each activity, the students practiced three hours. The selected activities were applied in the study group based on the inquiry-based STEM approach and worksheets were created. In the inquiry-based approach, the student establishes a hypothesis about the outcome of the experiment. Then, (s)he designs experiments related to the hypothesis (s)he has established, makes observations and experiments, records the data, analyzes and interprets the results.

In the application phase of the research, the study group students were left alone with a problem in the inquiry-based STEM activities and they were asked to design products for the solution of this problem. They were expected to benefit from science, technology, engineering and mathematical sciences in order to reach the result for the products they were asked to design. It is designed to contribute to 21^{st} century skills of the students and the activities enable students to develop creativity, productivity, teamwork, research inquiry, reasoning, decision making, critical and analytical thinking, understanding inter-system relations, etc. After this preparation period, another expert reviewed the activities. The STEM program planned for the research was finalized by making changes in the instructions and contents of the activity, taking into account the feedback of expert and an inquiry-based STEM activity booklet is prepared for the participants. In the figures below, there are some sample products that are performed by the preservice teachers for each different problem (Figure 2).

Figure 2. Sample products from the STEM activities

In the research process, students needed scientific knowledge to accomplish each design. In order to reach this scientific knowledge, they conducted experiments, collected data and made conclusions by operating an inquiry process. They also had to use basic mathematical skills such as calculating, measuring, matching, and calculating. Additionally, they offered solutions with the scientific results they obtained. They evaluated the proposed solutions as a group and evaluated them in the context of the criteria and limitations of their designs. In the last stage, students presented their designs and the process of creating this design to their classmates. Some of the STEM group activities of the 10-week implementation period of the research are given in Table 1.

Table 1. Research Process

Week	Issue	Inquiry based STEM Activity
1	Pretest of VASI Scale & Semi-Structured Interviews	
2	Life Sciences Activity	Natural Energy Production
3	Physical Sciences	Designing a Lampshade
4	Earth And Space Sciences	Space Technologies
5	Matter Science	Heat Loss
6	Unifying Concepts and Processes in Science	Being a Software Engineer
7	Personal And Social Science	Light Pollution
8	Science And Technology	Artificial Intelligence
9	History And Nature of Science	Fly Like da Vinci
10	Posttest Of VASI Scale & Semi-Structured Interviews	

In the last stage, after the activities were completed, pre-service primary school teachers were provided with the opportunity to develop their engineering skills, critical and analytical thinking skills, as well as to make presentations to their peers, ask or answer questions and exchange views. In this way, their communication skills were also supported. At the end of the activities, they were asked to promote their designs with posters and product models in order to improve their written communication skills, contribute to their entrepreneurial skills and reflect their scientific achievements. The implementation of the activities took 10 weeks/30 lesson hours.

Data Collection and Analysis

In this study, mixed method was used in order to set research design. As mentioned above, the purpose of this method is to simultaneously collect both quantitative and qualitative data, and also analyze and compare the results. Therefore, quantitative data via Views About Scientific Inquiry (VASI) developed by Lederman (2014) and qualitative data via semi-structured interviews were collected. The quantitative data were analyzed statistically via IBM SPSS Statistics, qualitative data were descriptively. Shapiro Wilk test was used to test the normal distribution of the data. For the normally distributed data of VASI, the dependent samples t-test was applied. The dependent sample t-test was used to determine whether there was a significant difference between the pre-test and post-test scores of the study group after the STEM activities. The dependent sample t-test was used to determine whether there was a significant difference between the pre-test and post-test scores after the scientific method-based STEM applications. p significance level was accepted 0,05 in order to reveal the significant differences of the results. Pre and post comparison of the data obtained from VASI questionnaire were conducted.

VASI was used in order to determine the effect of STEM education on preservice primary school teachers' scientific inquiry understandings and skills. According to Lederman et al. (2014) students need to develop a deep understanding about some aspects of scientific inquiry. In this way, they can better understand how the nature of science works, how scientists make discoveries, and how they reach 'knowledge'. This perspective of scientific understanding includes eight aspects about scientific inquiry (SI). Specifically, students need to develop an informed understanding of the aspects of SI (see Table 2). This form of the scale was developed by Lederman et al. (2014) and adapted into Turkish by Cavus-Gungoren and Ozturk (2017; 2021). VASI was developed to identify students', preservice teachers' and scientists' views on scientific inquiry and understanding. It focuses on different skills of inquiry and tries to find out individuals' perceptions and knowledge about science. Due to the nature of the assessment tool, pre-service teachers should think, criticize and reason about scientific inquiry.

It is a scale consisting of seven open-ended questions about the eight characteristics of scientific inquiry. By making a holistic analysis, participant views on scientific inquiry characteristics are categorized in a continuum as "unclear, naive, transitional and informed". When assessing each aspect of SI, views are categorized as informed, transitional, naive, and unclear. If a respondent provides a response consistent across the entire questionnaire that is wholly congruent with the target response for a given aspect of SI, they are labeled as "informed." This shows that he has sufficient knowledge and skill in the dimension. If, by contrast, a response is either only partially explicated, and thus not totally consistent with the targeted response, or if a contradiction in the response is evident, a score of "transitional" is given. This type of responses includes answers that are partially true or false. A response that is contradictory to accepted views of a particular aspect, or provides no evidence of congruence with accepted views of the specific aspect of SI under examination, is scored as "naive." Lastly, for scores that are incomprehensible, unintelligible, or that, in total, indicate no relation to the particular aspect, a categorization of "unclear" is assigned (Lederman et. al., 2014). The Cronbach alpha reliability value of the VASI results in this study is 0,969.

Table 2. Aspects of scientific inquiry and corresponding items on VASI questionnaire (Lederman et. al., 2014)

Aspect of Scientific Inquiry	VASI Item
1. scientific investigations all begin with a question and do not necessarily test a hypothesis	1a, 1b, 2
2. there is no single set of steps followed in all investigations (i.e., there is no single scientific method)	1b, 1c
3. inquiry procedures are guided by the question asked	5
4. all scientists performing the same procedures may not get the same results	3a
5. inquiry procedures can influence results	3b
6. research conclusions must be consistent with the data collected	6
7. scientific data are not the same as scientific evidence	4
8. explanations are developed from a combination of collected data and what is already known	7

In the analysis of the normality of the distribution of the data obtained from the scientific inquiry questionnaire of the preservice primary school teachers, it is seen that the result of the "Shapiro Wilks" test is p=.83 (pre-test) p=.21 (post-test). Since these values are greater than 0.05, the pre-test and post-test score distribution is considered to be normal. For this reason, the data were analyzed with the dependent sample t-test, one of the parametric analysis methods.

Semi-structured interviews were conducted with approximately 20% of the respondents to confirm that the respondents gave responses consistent with the purpose of the survey. The interview form is developed by the researcher in parallel with the VASI scale. All interviews were recorded with a voice recorder and transcribed. Then the questionnaire was coded according to the answering criteria.

A deeper examination of the opinions of individuals was made with semi-structured interviews. Participants were confirmed by reminding the answers they gave during the interview. Document analyzes made as a result of data diversity were used to confirm each other. In the literature, researchers (Cresswell, 2007; Merriam, 2013) have made suggestions in this direction. In order for the analyzes to be carried out consistently, analysis forms and forms in similar studies were examined and analysis forms suitable for the research were created accordingly. In line with these forms, the findings were reviewed multiple times, paying attention to the consistency of the findings obtained from different data sources and among themselves.

Semi-structured interviews were carried out with preservice primary school teachers after the implementations with the intention of supporting the data obtained from VASI questionnaire to determine the effect of STEM education on students' scientific inquiry understandings and skills. The preservice teachers chosen for the interviews were selected via convenient sampling. Participants performed the activities in groups and each group was numbered by the researcher (G1, G2, G3…, G8). Individuals selected from each of the eight groups were interviewed. Interview findings were evaluated by two experts in the light of the aims of the research.

Table 3. Semi-structured interview questions

	Scientific Inquiry Aspects	Questions
Scientific Inquiry Understandings and Skills	Scientific investigation beginning	Two students are asked if scientific investigations must always begin with a scientific question. One of the students says "yes" while the other says "no". Whom do you agree with and why? Give an example. Do they necessarily test a hypothesis?
	Scientific method types	Do you think that scientific investigations can follow more than one method? Are there just a single scientific method?
	Inquiry procedures	Are the inquiry procedures guided by the question asked? Is there any other way of guiding inquiry procedures?
	Same procedure-same results	Do all scientists performing the same procedures may not get the same results?
	Inquiry procedures versus results	If several scientists ask the same question and follow different procedures to collect data, will they necessarily come to the same conclusions? Explain why or why not. Do inquiry procedures can influence results?
	Data and research conclusions	Should the research conclusions must be consistent with the data collected?
	Scientific data versus evidence	Is the scientific data the same as scientific evidence? How do they differentiate from each other? Please give an example.
	Scientific explanations derived from data	Are the explanations developed from a combination of collected data? When scientists do any investigation, what type of information do they use to explain their conclusions?
STEM Activities	STEM-Inquiry Relations	Did STEM activities change your scientific perspective? What do you think about science, technology mathematics and engineering relations in terms of scientific inquiry procedures? Did the activities carried out throughout the process have an effect on your opinions/ideas about science, technology, engineering, and mathematics?

According to the Table 3, the semi-structured interview included two parts of questions as questions about scientific inquiry and about STEM activities. Within the scope of research, the questions in Table 2 were asked to the participants in order to compare and verify their responses. Interviews were carried out with 10 students (at least %20 of the study group). The interviews lasted an average of 11 minutes.

Considering ethics in the research, the confidentiality of the participants was given importance. While processing the data obtained during the research process; STEM groups were coded as G1, G2, G3…G8, and the pre-service teachers in these groups were coded as 1,2,3…47. Participants were informed in advance about the purpose and the whole process of the study, and interviews were conducted with the measurement tool application in this direction. In addition, while photographing the products taken during the applications, care was taken not to show the bodies and faces of the individuals.

Results

The purpose of this study is to determine the effect of STEM education on the preservice primary school teacher's scientific inquiry skills and understandings. In line with this purpose, research questions are focused on the level of preservice primary teacher's scientific inquiry skills before taking any training about STEM education and how does the STEM education affect development of the preservice primary teachers' scientific inquiry skills.

The Findings about Preservice Primary Teachers' Inquiry Skills before STEM Activities

On the pre-test data obtained in the first part of the study, the initial states of the pre-service primary school teachers' scientific inquiry skills were examined. Descriptive statistics according to the data are presented in the Table4 below. As seen in Table 4, at the beginning of the study, while on average, 23.5% of the pre-service teachers gave unclear answers to all dimensions of scientific inquiry, 40% in total gave inadequate and mixed answers. The percentage of participants who are seen to have informed opinions is 37,26. That is, pre-service teachers' views on scientific inquiry are insufficient. Although they took courses on basic positive sciences such as physics, chemistry, biology and mathematics until this level of education, it is striking that they are insufficient in different dimensions of scientific inquiry. This means that taking courses on positive sciences is not enough to develop scientific understanding and develop an opinion about scientific methods and processes.

Table 4. Frequencies and percentages of eight aspects of SI before STEM education

Aspects of Scientific Inquiry	Unclear		Naïve		Transitional		Informed	
	f	%	f	%	f	%	f	%
SI 1. Scientific investigations all begin with a question and do not necessarily test a hypothesis	7	15	6	13	30	64	4	9
SI 2. There is no single set of steps followed in all investigations (i.e., there is no single scientific method)	9	19	11	23	16	34	11	23
SI 3. Inquiry procedures are guided by the question asked	17	15	3	6	0	0	27	79
SI 4. All scientists performing the same procedures may not get the same results	15	31	7	14	6	12	19	40
SI 5. Inquiry procedures can influence results	18	38	3	6	4	9	22	47
SI 6. Research conclusions must be consistent with the data collected	3	6	24	51	1	2	19	40
SI 7. Scientific data are not the same as scientific evidence	15	32	1	2	17	36	14	30
SI 8. Explanations are developed from a combination of collected data and what is already known	15	32	1	2	17	36	14	30
Average number in total of participants about different SI views	12,75	23,5	7,00	14,63	11,37	24,13	16,25	23,50

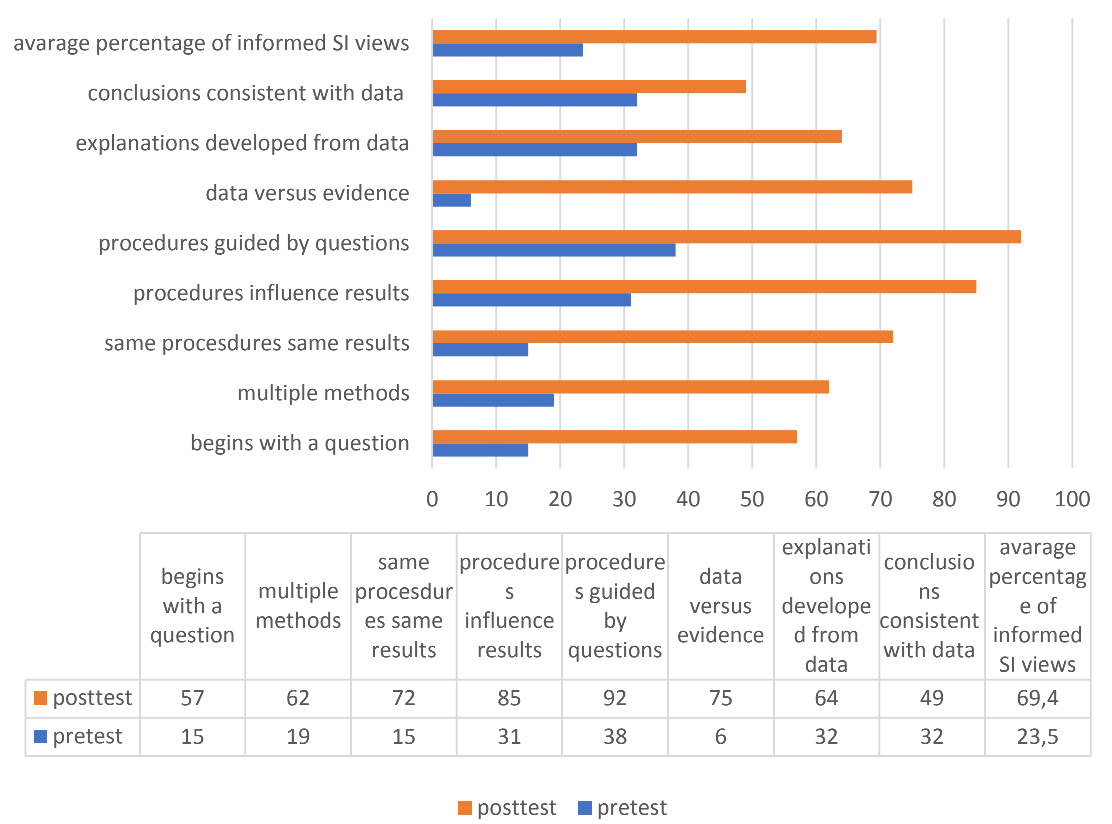
The Findings Related to the Effects of STEM Education on Preservice Primary School Teachers' Scientific Inquiry Skills

In the second research question; it is tried to find out that is there a significant difference between the scientific inquiry understandings and skills pre-test and post-test understandings of the study group participants after STEM applications. In order to answer this question dependent sample t-test was conducted to compare the pre-test post-test descriptive statistics of the scientific inquiry skills and understandings of the study group participants. Accordingly, there was a significant increase in different aspects and total SI views (see Table 5). The frequencies of students categorized as unclear, naive, transitional and informed views across aspects of scientific inquiry before and after getting STEM activities are illustrated in Table 5.

Table 5. Frequencies of scientific inquiry before and after getting STEM activities

	Begins with a question		Multiple methods		Same procedures-same results		Procedures influence results	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Unclear	7	0	9	9	17	12	15	5
Naive	6	11	11	3	3	1	7	2
Transitional	30	9	16	6	0	0	6	0
Informed	4	26	11	29	27	34	19	40
	Procedures guided by questions		Data is not same with evidence		Explanations developed from data		Conclusions consistent with data	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Unclear	18	4	3	1	15	10	15	3
Naive	3	0	24	10	1	0	1	1
Transitional	4	1	1	1	17	7	17	20
Informed	22	42	19	35	14	30	14	23

As seen in Table 5 (N=47), there is an increase in all dimensions of scientific inquiry after STEM applications. For easier and better understanding, the pre- and post-application data has been graphed. The graph focuses on the state of informed views on scientific inquiry since it is thought that the effectiveness of STEM applications and the increase in the understanding and skills of real scientific inquiry will reflect the informed opinions.



	begins with a question	multiple methods	same procesdures same results	procedures influence results	procedures guided by questions	data versus evidence	explanations developed from data	conclusions consistent with data	avarage percentage of informed SI views
posttest	57	62	72	85	92	75	64	49	69,4
pretest	15	19	15	31	38	6	32	32	23,5

Figure 3. Percentages categorized as informed views of SI before and after getting STEM activities

Results indicated that the majority of students were given unclear (%23,50), uninformed (%14,63) and transitional (%24,13) responses (see Table 4) and minority (%23,50) had informed views in their conceptions of scientific inquiry before STEM activities. However, after the implementation, the percentage (%69,4) of the participants informed views and understanding about scientific inquiry and its aspects has increased meaningfully. In order to examine whether there is a significant difference between the pre-test and post-test scores of the pre-service teachers, first of all, the normality of distribution was tested. The effect size of the difference was interpreted by calculating eta square values. Effect values found (d value) .01 small effect size; .06 medium effect size; .14 was interpreted according to the large effect size (Büyüköztürk, 2002) limit values. The dependent sample t-test data regarding the significance of the difference between the VASI pre-test and post-test scores of the participants after STEM applications are given in Table 6.

Table 6. Results for the comparison of pre-test and post-test scores of SI

Scale	N	X	Sd	t	p
SI Pre-test	47	91,24	1,054	-5,734	,001*
SI Post-test	47	166,62	1,329		

$p<.05$

As seen on Table 6, there is a significant difference between the participants' pre and post test results of SI in favor of post-test ($p<.05$). This result can mean that STEM based applications have a positive effect and on preservice primary school teacher's scientific inquiry skills and understandings. It is thought that this is due to the fact that these activities, which require the use of science, technology, mathematics and engineering skills, are carried out by following the scientific methodology. The participants needed to hypothesize the problem, used questioning, collected and verified data, designed and created a product in the light of data and also used communication skills.

Table 7 provides example responses to each of the VASI items. These are verbatim quotes selected from the responses of preservice primary school teachers. The naive view respondent examples are taken from pretests and the more informed examples are taken from students' posttests. These views are presented along a continuum from naive to more informed understandings of SI.

Table 7. Exemplary responses of preservice primary school teachers about eight aspects of SI

SI Number	Naïve views (Before STEM education)	Informed views (After STEM education)
SI 1.	"No, I think she reached a conclusion based on her own observations, not scientifically." (G4-38)	"Yes, it is scientific. It's not an experiment. Observation used" (S4-38)
SI 2.	"Team B because roads matter, not tire performance." (G5-7)	"Team A is better. They tested the performance of different tires in three different ways. Their conclusions will be more accurate and precise. More than one method can be used, by the way more precise solutions are obtained." (G5-7)
SI 3.	"B team is better because it does it under equal conditions." (G3-28)	"It is limited to examine three tires of a brand, so Team A took the better route. They tested the performance of different tires in three different ways. Their conclusions will be more accurate and precise." (G3-28)
SI 4.	"Yes, the sources used may differ, but scientific knowledge is one. The results should be the same." (G1-9)	No. Because they have different experiences. Scientists will also have personal differences and different perspectives." (G1-9)
SI 5.	"Yes, they reach the same conclusion. Because science is based on objective data." (G6-36)	"No, different questions lead to different steps and different results." (G6-36)
SI 6.	""No, they have to grow as the daylight increases. Also, different types of plants can have different lengths with different amount of light." (G8-2)	"Plants grow more with less sunlight." (G8-2)
SI 7.	"It is not different. Data is the result, so is the evidence, but it has a validity." (G7-30)	"It is different. If the information we obtain is evidence, it is the proof of the accuracy of this information." (G7-30)
SI 8.	"What you already know is not important and does not affect results" (G2-23)	"Scientists reach the conclusion by adding information on the results in a certain order and on the known information, scientific information." (G2-23)

In addition to these views, the views of pre-service primary school teachers about the activities carried out within the scope of science-technology-engineering-mathematics combination were taken and their answers about scientific inquiry processes were examined.

Table 8. Exemplary quotations related to scientific inquiry

	Responses of preservice primary school teachers before and after STEM education
STEM- Inquiry Relations	"When we completed the activities, I realized that I didn't know much beforehand. So scientific knowledge alone was not enough." G3-28 "I used to think that data and evidence were the same concepts. I realized that especially the data we obtained while building the space rocket and the evidence we used for decision making were not the same." G2-23 "In my opinion, knowing only physics and mathematics courses is not enough to develop in science. Our activities were tangible. It's like it helped us make a connection between knowledge and practice." G1-9 "In my opinion, STEM is very effective for developing scientific understanding. After the activities we did, I felt that I had improved in this regard." G7-30 "We need to think critically and analytically. It was hard and brainstorming." G5-7

As seen above, most of the pre-service teachers stated that STEM-based education practices improved them in terms of scientific inquiry. They especially emphasized that their scientific knowledge and opinions before the application developed after the applications. At this point, it can be concluded that STEM applications establish a connection between these scientific disciplines in teacher candidates and they have a more effective idea about the functions of science. Some of the participants also emphasized the concretization of knowledge. They stated that it is necessary to use many thinking skills actively in the formation process of the resulting products. The results support the data obtained from the scale to reflect the pre-service teachers' understanding of the eight dimensions of scientific inquiry.

Conclusion and Discussion

This research aims at determining the effect of STEM education on the preservice primary school teacher's scientific inquiry skills. Results of the study reveals that at the beginning of research, pre-service teachers' views on scientific inquiry are insufficient before taking any STEM education. Although they took courses on basic positive sciences such as physics, chemistry, biology and mathematics until this level of education, it is striking that they are insufficient in different dimensions of scientific inquiry. This means that taking courses on positive sciences is not enough to develop scientific understanding and develop an opinion about scientific methods and processes.

In the second research question purpose, it is tried to find out is there a significant difference between the scientific inquiry understandings and skills pre-test and post-test understandings of the study group participants after STEM applications. Accordingly, there was a significant increase in different aspects and total SI views (see Table 5 and 6). In other words, there is an increase in all dimensions of scientific inquiry after STEM applications. It is thought that the effectiveness of STEM applications and the increase in the understanding and skills of real scientific inquiry will reflect the informed opinions. STEM based applications have a positive effect and on preservice primary school teacher's scientific inquiry skills and understandings. It is thought that this is due to the fact that these activities, which require the use of science, technology, mathematics and engineering skills, are carried out by following the scientific methodology. The participants needed to hypothesize the problem, used questioning, collected and verified data, designed and created a product in the light of data and also used communication skills. Within the interviews, most of the pre-service teachers stated that STEM-based education practices improved them in terms of scientific inquiry. They especially emphasized that their scientific knowledge and opinions before the application increased after the application. At this point, it can be concluded that STEM applications establish a connection between these scientific disciplines in preservice teachers and they have a more effective idea about the functioning of science. Some of the participants also emphasized the concretization of scientific knowledge. In another study conducted with preservice teachers, the students expressed a positive opinion on the STEM education that it provided the development of scientific process skills and increased their attitude and motivation towards the course (Sarı, Duygu, Şen & Kırındı, 2020).

Considering the developments in recent years, the abbreviation STEM has a wide place in education and policy studies of many countries, especially the USA (Honey, Pearson & Schweingruber, 2014). Many of the fastest-growing professions today require significant science or math education. In this sense, it is necessary for students to have solid STEM knowledge for employment (Becker & Park, 2011). Additionally, in response to pedagogical challenges in 21st century education, STEM based learning has become a prevalent practice in schools, colleges, and universities (Abdurrahman et al., 2019). Some studies illustrate those negative approaches to science begin at primary school level (Abell & Lederman, 2006, Keeley, 2009). For this reason, it is very important for primary school students to learn scientific content that will form the basis of science education with an appropriate program and effective teaching methods. Moreover, a strong positive relationship has been found between students' science-related experiences at elementary school and the choice of future studies in STEM disciplines (Tai, Qi Liu, Maltese & Fan, 2006). At this point, the effect of STEM-based activities emerges. In today's world, teaching activities that integrate the fields of science, technology, mathematics and engineering will not only contribute to the development of the child's scientific skills, but will also support many skills such as high-level thinking skills, communication, research and inquiry. Thus, it will be possible to get closer to the targeted educational gains in 21st century skills. At this point, primary school teachers have a lot of work to do. Classroom teachers, who aim to bring scientific understanding to children, should also be knowledgeable about scientific inquiry and these issues. It cannot be expected from a teacher without these knowledge and abilities to teach scientific inquiry to his students.

It is very important to carry out theoretical and applied education experiences together in the professional development of preservice teachers (National Science Teachers Association [NSTA], 2004, 2006). Although the participants in this study took theoretical lessons on positive sciences such as biology, chemistry, physics, mathematics etc. during their education process, it was seen that they had a low level of scientific inquiry understanding and skills in the results obtained from the first test. In other words, training given only in theoretical content is not sufficient to develop scientific understanding. Since the STEM activities applied during the study process included many disciplines practically, they created the chance for preservice teachers to activate scientific knowledge in practice. At this point, more applied scientific activities can be included in teacher education programs. STEM can be seen as an integrative education that brings together many scientific disciplines. Therefore, STEM application programs can be expanded both in primary schools and with teachers who will train children. In fact, considering that scientific understanding has started to develop in the pre-school period, highlighting STEM and scientific understanding in early childhood education can also support children's armament with 21st century skills. In order for countries to shape and upgrade their future policies according to the understanding of the age, it is recommended that these experiences be delivered to almost every child by spreading STEM studies at all levels of education. Finally, this research was limited to the variable of scientific inquiry. It is recommended to conduct more comprehensive studies with different variables.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the author.

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