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The Effects of STEM Education on Scientific Process Skills and STEM Awareness in Simulation Based Inquiry Learning Environment

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ABSTRACT

In this study, the effects of STEM education in the simulation–based inquiry learning (SBIL) environment on the students' scientific process skills and STEM awareness were investigated. In addition, the use of simulations in STEM education was discussed by evaluating students' views on activities. Study group of the research consists of 39 students enrolled in science teaching undergraduate program at a university in Turkey. Results of the study showed that STEM education performed in the SBIL environment has a positive effect on the development of scientific process skills and STEM awareness. 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. The students stated that the simulation program used in the STEM activities provided important advantages such as designing and developing engineering products, experiments and reducing errors.

Keywords: STEM; inquiry learning; computer simulation; scientific process skills; awareness.

INTRODUCTION

Over the last decade, STEM education has been increasingly popular and it is considered one of the most important emphases in contemporary science education reform movements (Wu & Anderson, 2015; Gül & Taşar, 2020). STEM (science, technology, engineering and mathematics) education involves integration of several disciplines, primarily four disciplines. It is argued that STEM education is vital for students to develop 21st century skills such as problem solving, innovation, creativity, communication and collaboration

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(Bybee, 2010; Cooper & Heaverlo, 2013; Çepni, 2018). For this reason, STEM education has become crucial in bringing the students to a level that can compete at the global level in the 21st century (Breiner et al., 2012). In STEM education, students seek solutions to real life problems. The problems encountered in real life have an interdisciplinary nature and cannot be limited to the knowledge and skills of a particular discipline. Therefore, in order to solve these problems, students must use the interdisciplinary approach of knowledge and skills of different disciplines by its nature (Wang, 2012; Wang et al., 2011). Many researchers emphasize the need for an integrated education in which interdisciplinary boundaries are removed for an effective STEM education (Breiner et al., 2012; Morrison & Bartlett, 2009).

On the basis of STEM education; there is an inquiry approach that drives students to research, produce and make new discoveries. Therefore, STEM learning environments should be arranged in this direction and so it can provide opportunities for students to develop 21st century skills such as problem solving, critical thinking and creativity. In this context, STEM education is a process in which students collaborate with scientific inquiry and engineering design in collaborative environments to solve real life problems (Suratno, et al., 2020). In this process, teachers guide the students to question the main problem they have faced and provide the opportunity for students to find solutions to the problem on their own. At this point, inquiry-based learning constitutes the pedagogy of STEM education (Crippen & Archambault, 2012). For this reason, teachers have a key role in integrating STEM into courses.

In the 21st century, when knowledge and technology grew exponentially, educators and researchers increasingly stressed the potential power of educational technology to improve STEM learning outcomes (Wu & Anderson, 2015). Therefore, the use of educational technologies such as augmented reality, simulations and robotic applications has become an important issue for researchers in STEM education (Wu & Anderson, 2015). Researches show that simulations can provide STEM literacy development (Rutten, van Joolingen, & van der Veen, et al., 2012) and STEM awareness in students (Gül & Taşar, 2020). D'Angelo et al. (2013) argued that the positive effects of the simulations are evident in studies, but there is still a lot to learn about the educational benefits of computer simulations in STEM areas. One of the important research topics in STEM studies is simulation-based inquiry learning. Also, scientific process skills are central to STEM education.

In this study, undergraduate students of science education were encouraged to solve the engineering problems in a simulation-based inquiry learning environment. The aim of this study is to investigate the effects of STEM education on STEM awareness and scientific process skills and to evaluate students' opinions about using STEM applications and simulations. For this purpose, research problems have been created as:

1. Is there a statistically significant difference between STEM awareness levels of students before and after the practice?
2. Is there a statistically significant difference between the scientific process skills of the students before and after the practice?
3. What do students think about the use of simulation in inquiry-based STEM education?
4. What are the students' views on the use of the simulation program in STEM applications?

Theoretical Framework

Inquiry based learning (IBL) strategy in STEM education

According to Sanders (2009), STEM education should focus on the application of mathematics, science and engineering knowledge, designing and executing experiments, analyzing and interpreting data, and corporate communication with teams from different disciplines. An effective STEM education should not only focus on the content of science, but also encourage understanding and evaluation of curiosity, evidence-based reasoning, and scientific inquiry processes (). In addition, in the analysis of STEM programs and curriculum design; by developing a solution, problem solving and inquiry emerge as two major focuses of STEM integration (Morrison & Bartlett, 2009). Therefore, teaching STEM integration should not only focus on content knowledge, but also problem-solving skills and inquiry-based learning. STEM learning environments promote creativity through the use of inquiry approach, offer opportunities for teamwork, and emphasize inquiry rather than memorization information (Wang et al., 2011). In inquiry-based learning, students produce their own scientific questions, develop critical questions, search for possible solutions, prioritize evidence in answers to questions, generate explanations from evidence, link to scientific information, communicate, and share findings (Imaduddin & Hidayah, 2019; Rushton, Lotter & Singer, 2011).

Inquiry-based learning focuses on original problems and issues related to students and the daily life. In addition to the aspects to be learned, students play an important role in determining the questions to be examined. In this approach, where deep understanding is intended, learning is done through the study, design, modeling, interviews, research and other active discovery types that lead students to new understanding. Teachers facilitate the learning process by guiding students and structuring the learning environment (Li, Moorman & Dyjur, 2010). The inquiry-based learning is characterized by questioning, practical activity and critical thinking in science classes (Gerber et al., 2003). Students are encouraged to question, to do research, to learn, to report their effects and to evaluate their knowledge (Van Zee & Roberts, 2006). Among the benefits of using the inquiry approach are further preservation of factual information, greater flexibility and creativity in problem solving, and ensuring student motivation (Lord & Orkwiszewski, 2006). The integration of STEM education can be achieved through the operation of the engineering design cycle in the inquiry-based learning process. In this study, a five-stage inquiry-based learning cycle proposed by Lim (2004) was used. These stages and brief definitions are given below:

1. Ask: The students brainstorm about the scope of the problem and the issues that involve solutions.
2. Plan: Students plan the solution process of the problem.
3. Explore: Students do research to solve the problem and collect data for solution.
4. Construct: Students analyze research data and provide solutions.
5. Reflect: Students discuss problem solutions and results.

Computer simulations in Inquiry-Based Learning Strategy

Computer simulations such as animations and virtual labs provide theoretical or simplified models of real-life processes and phenomena (Smetana & Bell, 2012). Simulations can help in the implementation of educational reforms by facilitating inquiry-based learning and provide STEM literacy development in students (Rutten, van Joolingen & van der Veen, 2012). They also play a critical role in helping students visualize scientific facts (Srisawasdi, Kerdcharoen, & Suits, 2008). They enable the complex and invisible nature of the concepts to be visual (Rutten et al., 2012). Moreover, students observe, discover, rebuild, and receive immediate feedback about real objects, events and processes with simulations presenting dynamic theoretical or simplified models of phenomena. Students can also do a virtual experiment with changing variables and recording scientific results with interactive simulations. They encourage active participation in higher-order thinking and problem solving and facilitate learning of abstract concepts (Mcdonald, 2016). Simulations for inquiry-based teaching are a promising field in terms of strengthening students' mental interaction with the physical and social world to develop a scientific understanding, explanation, and communication between science ideas (Srisawasdi & Panjaburee, 2015). If students want to have an active role in their own learning process, the simulations can be used to support authentic inquiry activities, including creating questions, developing hypotheses, and collecting data (Rutten, Joolingen & Van der Veen, 2012). In a simulation-based inquiry, students come across two processes as transformational and regulatory (Njoo & De Jong, 1993). In transformational process, students produce direct information with forming a hypothesis, designing experiments, drawing a conclusion. In orientation process, students associate the variables, conditions and events presented in the problem, identify important variables and visualize the simulation conditions. Regulatory process means planning and monitoring the learning process (Linn et al., 2004). As a result, the simulations can play an active role in STEM teaching, in terms of both supporting the inquiry processes and providing a modeling opportunity.

METHODS

Mixed method research was preferred because quantitative and qualitative methods were used together. The mixed method is defined as the combining of qualitative and quantitative methods, approaches and concepts in a study (Johnson, & Onwuegbuzie, 2004). The purpose of the mixed method is to expand the understanding of the event (Leech & Onwuegbuzie, 2009). In the quantitative dimension of the study, single group pre-test post-test experimental design was used. In this model, an experimental group was formed on a voluntary basis. The Scientific Process Skill Test and STEM Awareness Scale were applied as pre-test and post-test in order to examine the changes in students' scientific process skills and STEM awareness. In the qualitative dimension of the study, the students' views on STEM activities were collected via a semi-structured interview form. In order to support the findings obtained in the quantitative dimension of the research, students' opinions were examined at the end of the research.

a) The Study Group

In order to determine the study group, convenience-sampling method was used from purposeful sampling methods. Easy-to-use status sampling, which is widely used in qualitative research, provides an advantage in terms of cost and time (Yıldırım & Şimşek, 2011). For this purpose, considering the laboratory facilities, technological infrastructure and suitable class size for STEM activities, the research was carried out with 39 undergraduate students (34 girls and 5 boys) who are enrolled in General Physics Laboratory III course in the second year of Science Education Program in a university in Central Anatolia, Turkey.

b) Development and Implementation of STEM Activities

In the study, five simulation-based inquiry-learning activities were conducted within the scope of the Physics Laboratory III course. The application was carried out over 2-hour course per week for 10 weeks. Each activity lasted for 2 weeks (4 lessons) in the areas of diffusion of light, reflection in the mirrors, refraction of light, lenses, mirrors and the use of lenses. The learning objectives and the briefs of STEM with IBL activities are given in Table 1. Each activity starts with a scenario containing a real-life engineering problem. Students completed the 5-stage inquiry cycle (Lim, 2004) and 4-stage engineering design processes (Wendell et al., 2010) to solve the engineering problem given in the scenario simultaneously.

Table 1. *Learning objectives and the brief STEM with IBL activities of each lesson*

STEM Activities	Learning Objectives	Science	Technology	Engineering	Mathematics
1- Spreading of Light “Melek's Village Adventure “	- Knows that engineering design process consists of steps that can be used to solve problems. - Knows that a light from a source follows a linear path in every direction and shows with drawing. - Explains the relationship between the reflected beam, the normal of the surface and the incoming beam without reflection. - Realizes the negative effects of light pollution and explains.	Light source, light rays, reflection in light, light diffusion, light pollution	Selection of materials to be used in the illumination tool, usability and cost. The use of simulations in model design	Preparation of different designs for light pollution solution, decision making, preparation and application of the most appropriate selection.	Determination of distance of light source from ground, Determining the angle of the light source with the ground
2- Mirror Reflection "Technology in Wars"	- Knows that optical engineers use science and mathematics knowledge to solve their problems. - Compares the images formed in straight, pit and bump mirrors. - Explains the relationship between the reflected beam, the normal of the surface and the incoming beam without reflection - Knows image formation and image properties.	Reflection of light in mirrors, reflection laws, image formation and properties, special situations and concepts in mirrors	Selection of materials to be used in periscope design, usage and cost, periscope modeling by simulation	A system to safely show against the pit area “periscope” design and implementation	Measuring how many degrees of light are reflected in parallel by mirror. Measuring how many degrees of light are reflected in parallel positions of mirrors in different positions. Associating the laws of reflection with the subject of angles.
3- Light Breaking “The Secret of Illusionists”	- Associates the cause of the breaking event with the change of environment. - Analyses the full reflection event of light and boundary angle.	Laws of refraction and refraction in light, full reflection event	Selection of materials, usability and cost, Design modeling using simulation	Making and applying a design that describes the phenomenon of light breaking which is one of the techniques used by illusionists during their demonstrations.	Mathematical calculations related to Snell's law
4-Lens ”Movie Show“	- Explains the properties of lenses and types of lenses. - Explains the properties of images formed by lenses. - Makes drawings about image formation in lenses. - Gives examples of the use of lenses.	Special rays in the thin-edged lens image drawing; special rays in thick-edged lens, image drawing	Selection of materials to be used in projection design, usage and cost, simulation with projection modeling	Design, application, development for the engineering product (projection) to be prepared to watch the images on the filmstrip as watching movies	Defining focus and points by mathematical measurement and calculation according to the type of lens to be used
5-Combination of Mirrors and Lenses ”Pencil Drawing“	- Discovers combination of the use of mirrors reflecting light and the use of the lenses that break the light. - Makes original designs to solve problem solving. - Questions the characteristics that the design proposal should be different from similar products.	Reflection in mirrors, collecting or distributing light in lenses	Selection of design product materials, usability and cost, simulation modeling design	Engineering product design and application to be used for pencil drawing	Determining the point where the image is formed by using the combination of plane mirror and lens by mathematical measurement

Stages of STEM teaching with inquiry learning and the engineering design processes were given in Table 2. In this process, students engage in processes such as identifying the problem, collecting the necessary information for the solution, identifying hypotheses, and designing a virtual experiment to test. Taking into account the results of the experiments, the students made a design to solve the problem and developed their designs with creative ideas (Appendix A: Student study example). In the Explore stage, students conduct research to develop possible solutions to the engineering problem. In this context, they have designed and conducted a virtual experiment using simulations to test the hypothesis of the solution. They developed models with simulations and tried to find the most appropriate solution (Appendix B: Examples of students' simulation models). In this context, the Crocodile Physics 605 simulation program was used (http://crocodile-clips.com/en/). The Crocodile Physics program gives students the opportunity to conduct virtual experiments in electric, motion, optics and wave subjects in accordance with their own designs. Before the implementation of the activities, the use of this program was explained.

Table 2. *Stages of STEM teaching in inquiry-based learning strategy*

Inquiry based learning process	Engineering design process	Student Activity
Ask	Determining the scope of the problem, determining the need (criteria and constraints).	Brainstorm about the problem and the various solutions.
Plan		Plan the solution of the problem; determine how to use the method in the solution; how to collect the data and how to manage the time; list the known and unknown.
Explore	Doing the necessary researches for the development of possible solutions	Apply problem-solving strategies, collect data to solve the problem, establish hypotheses, design and perform virtual experiments to test, collect, analyze and interpret data; use simulations more at this stage.
Construct	Developing possible solutions, choosing the most suitable solution. Making, testing, evaluating and developing the prototype.	Make sense of the data, synthesize their findings, create new information and create a work; transforms the answer to their inquiry into action.
Reflect	Solution sharing, evaluation, improvement	Share problem solutions, engineering design products and learning outcomes; answer the question "What have I learned?"

c) Data Collection Tools and Analysis

In order to determine the awareness levels of teacher candidates about STEM, STEM Awareness Scale developed by Buyruk and Korkmaz (2014) was used. The scale is 5-point Likert type with 17 items. The Cronbach Alpha reliability coefficient of the scale was found to be 0.976. In order to determine whether there is a significant difference between the students' awareness of STEM before and after the application, Paired Sample t-test has been applied.

Scientific Process Skill Test (SPST) developed by Burns, Okey and Wise (1985) was applied as pre-test and post-test in order to measure the scientific process skill levels. Geban et al. (1992) adapted the test into Turkish. It consists of 36 multiple-choice questions. The Cronbach Alpha reliability coefficient of the test was found to be 0.77 (Geban et al., 1992). In this study, Cronbach Alpha reliability coefficient of the test was determined as 0.75. For each question answered correctly, 1 point and for each question answered incorrectly 0 point were given. The maximum score for the test is 36 and the minimum score is 0. In order to determine whether there is a significant difference in the students' scientific process skills before and after the application, Paired Sample t-test has been done. Cohen d (d) value was also calculated in this study.

Students' views were collected in order to determine the opinions about the simulation based feasibility study in the qualitative dimension of the application and to support the quantitative data after the application. For this purpose, a semi-structured STEM Interview Form (STEM-IF) consisting of 7 questions was prepared. The data obtained from this form were evaluated with content analysis technique. The content analysis is used to gather data similar to each other within the framework of certain concepts and themes and to arrange them in a way that the reader could understand (Yıldırım & Şimşek, 2011). In order to ensure the reliability of the measurements, two independent researchers determined the codes in each answer of the questions. Consistency of the categories formed by the researchers was determined by determining the number of consensus and differences of opinion in the process of comparing the categories. The reliability of the data analysis was calculated by using the reliability formula proposed by Miles and Huberman (1994) (Reliability % = Consensus / [Consensus + Disagreement]*100) and it was found to be 86.78%. The reliability over 70% is considered reliable for research (Miles & Huberman, 1994). In this research, the identity of the students is reserved, female students were coded as F1, F2, ... and for male students M1, M2, ... codes were used.

FINDINGS

a) Students' SPS and STEM awareness level before and after the SBIL activities

The present study investigated the changes in the students' STEM awareness and scientific process skill level as a result of SBIL activities. Moreover, the students' opinions about the SBIL activity integrated with STEM were also elicited and analyzed.

First of all, paired samples t-test was applied to compare the STEM awareness of the students before and after the activity. T-test results of STEM awareness pre-test post-test scores are given in Table 3. There is a statistically significant difference between the students' STEM awareness pre and post-test scores. The pre-test average of students was X = 2.82, while the post-test average was X = 3.54. Cohen d value was found to be 3.92. Consequently, it can be seen that the activities used during the applications have a significant positive effect on STEM awareness and have a wide impact value.

Table 3. *Comparison of paired samples t-test results of STEM awareness*

Tests	n	X	sd	df	t	p	d
Pre-Test	39	2,82	0,20	38	-15,56	,00	2,49
Post-Test	39	3,54	0,23				

Secondly, a *paired samples t-test* with pre and post test score of students SPST was applied to observe how the SBIL activities affect the students' SPS. The paired samples t-test results for the scientific process skills test are given in Table 4. There is a statistically significant difference between the pre-test and post-test scientific process skills test scores of the students. STEM education has a positive effect on students' scientific process skills. The effect size index was found to be 0.70 as medium effect size.

Table 4. *Comparison of paired samples t-test results of SPST*

Tests	n	X	sd	df	t	p	d
Pre-Test	39	19.77	3.21	38	-4.37	.00	0.70
Post-Test	39	24.18	5.18				

b) Students' views on SBIL activities that integrate STEM

The students' opinions about SBIL activities including STEM disciplines were gathered under three main themes (Table 5). The students determine that STEM education is effective in the fields of knowledge, skills and affective learning. The positive opinions expressed by the students are categorized as sub-themes under the main theme of “STEM's effect on learning” and the codes are given in Table 6.

Table 5. *Theme and sub-themes of student views about SBIL activities integrated with STEM disciplines*

Theme	Sub-themes
The effect of STEM on learning	Skill development Structuring and supporting information Attitude and motivation orientation Innovation
Challenges in STEM education	Challenges related to knowledge and skills Negative attitude Limitations
Use of simulation in STEM education	Advantages Disadvantages

When the answers to the question *“In your opinion, What skills can be developed when STEM education is received?* were examined; many students stated that their 21st century skills such as problem solving, creativity skills, analytical thinking, teamwork and cooperation have been improved. In addition, it was found that basic skills such as thinking skills, dexterity, ability to form hypothesis, and scientific process skills could develop (Table 6). Some student opinions on the subject are; *“Thinking and imagination skills develop because it is thinking how to do before doing something which is important in designs.”* (F1), *“It gives creative thinking skills because it teaches thinking more broadly.”* (M4), *“It contributes to group work and finding multiple solutions to problems.”* (F9).

When the answers to *“What contributions can STEM education make to science education as there is interdisciplinary interaction?”* were examined; the contributions to science education are gathered under the sub-theme of *“structuring and supporting knowledge”* (Table 6). The views of the students in this area were that the knowledge was realized and effective learning with grip and fun took place through the activities of SBIL. The opinions of some students on the subject are *"It is absolutely necessary for our education system because students learn to design what they think."* (M3), *"Collaborative work appears within the group. Students create self-confidence. It provides more permanent information."* (F19).

"Do you think it would be useful to perform STEM activities in your undergraduate study as a teacher candidate?" When the answers to this question were examined, it was seen that the most participation was gathered under the attitude and motivation orientation towards the course (Table 6).

Table 6. *Sub themes, codes and frequencies related with STEM's effect on learning*

Main Theme	Sub-Theme	Codes	Frequency (f)
Effect of STEM on Learning	Skill Development	Problem solving skills	25
		Thinking skill	22
		Development of dexterity	21
		Creativity skills	19
		Team work	9
		Setting up a hypothesis	9
		Ability to cooperate	8
		Analytical thinking skills	5
		Communication skills	3
		Critical thinking skills	2
		Mathematical Thinking	1
		Making a decision	1
		Specifying variables	1
		Psycho-motor skills	1
	Configuring and Supporting Information	Ensuring concretize	21
		Effective learning	15
		To be student-centered	9
		Ensuring comprehension	6
		Learning by fun	6
		Completing the topic	3
	Attitude and Motivation Orientation	Using your imagination	9
		Increasing interest in the course	9
		Professional development	8
		Providing student development	4
		Self-confidence	4
		Appreciation of events	2
	Innovations	Find the solution to the problem	16
		Interdisciplinary interaction	7
		Engineering product creation	6
		Determining the problem sentence	3

The most important point of the student responses about STEM's effect on learning is *to use the imagination, to increase the interest in the lesson and to provide professional development*. When the opinions of the students about the question are examined, 92.3% stated that the participation of STEM activities during the undergraduate education would contribute positively to their development. The other students in the remaining percentage did not express their opinions. Students on this subject stated that *"Students have positive features* *on to solve problems in everyday life more concretely, to develop imagination, and to increase handicraft"* (F26), *"I think that individuals should come to the course happily and curiously. To think new things and to design something excited me."* (F20), *"Students will learn to think creatively in this way."* (M4).

"What are the different aspects of STEM activities compared to previous applications?" When the opinions of teacher candidates were examined, it has been determined that differences between the problems of finding a solution to the problem, interdisciplinary interaction and engineering product formation are prominent. These codes are given under the theme *"innovation"* (Table 6). Students' opinions are *"There are a number of points that allow you to think fast, to quickly find solutions to problems."* (F7), *"Students are thought to find solutions to the problem and design."* (M3), *"We can see more than one discipline within a course. Not only science, we think more broadly"* (M4). Students stated different aspects of the activities (problem solving, interdisciplinary approach and engineering product) that are the basis of STEM education.

"Would you like to use STEM activities in your classroom when you become a teacher?" When the responses to the question were examined, 97.4% of the students stated that they want to use STEM activities in their classrooms when they become teachers. As a result of these responses, they stated that the activities could be effective in skill development, meaningful learning, and positive attitude and motivation. The opinions of some students on the subject are *"It helps to develop my students' visual intelligence designing, idea and hand skills."* (F3), *"We can make students think and design better and get more efficient results."* (F14), *"It will make students think multifaceted."* (F25). When these opinions are evaluated, it can be said that teacher candidates have quite positive opinions about STEM integration in science courses.

The difficulties of teacher candidates about SBIL activities including STEM integration were grouped into three sub-categories in Table 7. When the views of the students in response to the question of *"In which parts of these activities you have been challenged?"* were examined, it has been determined that students have difficulties related to knowledge and skills such as designing and creating engineering products, problem determination and creating hypothesis and experimenting (Table 7). Some students stated *"We were more tired in the design section. When we put the projects into design, we had a hard time together with*

Table 7. *Sub-themes and codes related with challenge in STEM education*

Main Theme	Sub-Theme	Codes	Frequency (f)
Challenges in STEM Education	Negative Attitude	Long duration of the event	14
		Activity strain	9
		To be tiring	3
		Emphasis on traditional application	2
	Challenges related to knowledge and skill	Challenges in designing and designing engineering products	13
		Challenges in determining hypothesis	12
		Challenges in identifying problems	11
		Challenges in communication within the group	4
		Challenges in making experiment	3
		Challenges in decision making	2
	Limitations	Lack of material	6
		Difficulty in application in crowded classes	3

our shortcomings." (F11) *"Hypothesis phase is harder because we had to work very much on it."* (F28), *"I had a hard time in the process of making a decision with my friends at the design stage and I had trouble getting in touch with them. Other than these, everything was fine. I was very happy to think about different things and to do different things."* (F10). In another sub-dimension, students expressed some negative attitudes and limitations such as long duration of activities, difficulties in activities, lack of materials and crowded classes.

To determine students' views on the use of simulations in STEM education, *"Has the simulation program you used during the applications had an impact on the engineering design process?"* was asked. The answers were evaluated in two sub-themes as the advantages and disadvantages of using simulation (Table 8).

Table 8. *Sub-themes and codes related with the use of simulation in STEM education*

Main Theme	Sub-Theme	Codes	Frequency (f)
Use of Simulation in STEM Education	Advantages	Ease of engineering design and development	29
		Facilitating the experimentation	14
		Use of information technologies	12
		Minimizing errors	9
		Save time	4
		Ease of access to materials	3
		Contributing to learning	2
		Contributing to thinking	1
		Ease of material determination	1
	Disadvantages	Inability to use the program effectively	8
		Limitations in the program	2

In general, students have positive views on the use of simulations in STEM education. About the advantages of the simulations, it is seen that the most participation is the facilitation of designing engineering products with 29 frequency values. Some students stated that *"We first designed the simulation. We tested the accuracy of our thinking with simulation and we started to implement it according to it."* (F1), *"It had an impact on the engineering design process."* (F13) and *"We tried to model the design with simulation and found the most useful option and simplified our design."* (F14). According to the views of the students, they decided to model the ideas they determined for the problem solving in the simulation environment and decided which was correct and designed according to the results. This situation is considered as the most important contribution of the simulations to the engineering design process. In addition, the students think that simulations are useful in eliminating the problems that may occur in the engineering design process and thus minimizing the errors. Some students stated that *"Thanks to the simulation we see what will happen as a result of the assembly and if it was wrong, we had the opportunity to change our design without installing the assembly."* (F23), *"The simulation program helped us design the product. We saw the product design on the computer and implemented it."* (F31).

As for the advantages of the simulations, in another dimension, the most participation was in the facilitation of experiment. Some students said that *"We were able to learn how to place and draw shapes on the computer, to prove the accuracy and inaccuracy of our hypotheses."* (F3), *"We can test the hypothesis on the use of lenses or mirrors, and if the image is formed on reflection and refraction. We can see the features of the image. We can make different applications."* (F25). When these expressions are evaluated in order to test the hypotheses the students have developed for the solution of their problems, they think that virtual experiments they designed using simulations provide convenience and they consider the simulations advantageous. In this case, it can be said that simulations contribute to the hypothesis determining, testing and experimenting stages which is one of the most important stages of the scientific inquiry process.

Although the students' opinions about the use of simulations in STEM education are generally positive, 8 students considered the disadvantage of using the program effectively, while 2 students considered the program as a disadvantage. The students interpreted the simulation program as disadvantage due to the use of the simulation program for the first time, adaptation and the difficulties they have experienced in the program. Students stated *"We are learning the new program. It takes time for us to understand and use it"* (F8), *"I had difficulty in the simulation activity we did on the computer because it is an application we're not familiar with."* (F12). According to these views, it is understood that some students have recently learned the simulation program used in activities, they have difficulty in engineering design process because of not being able to dominate the program and they cannot use simulation program effectively. It can be said that this situation causes students to evaluate them as disadvantages by developing negative attitudes towards simulations.

DISCUSSION and CONCLUSION

This study was planned to increase teacher candidates' STEM awareness level, to improve their scientific process skills and to investigate the use of simulations in STEM education. Both the scale and the interview results show that STEM education has a positive effect on STEM awareness of students in the simulation-based inquiry-learning environment. The students stated that STEM education could provide benefits such as improving imagination, increasing interest in class, providing professional development and academic development, and increasing self-confidence. Similar to the study conducted by Çınar et al. (2016), when the participants who encountered with integrated STEM applications for the first time explained the different aspects of STEM activities compared to previous applications, they emphasized especially the principles of STEM education such as interdisciplinary interaction and engineering product design. As a result, it can be said that STEM activities have positively developed STEM awareness. The increase in the level of awareness of the individual increases his conscious related to his / her awareness and environment (Buyruk & Korkmaz, 2016). Awareness affects people's attitudes positively. Hutton & Baumeister (1992) found that increasing the level of awareness facilitates transformation of awareness into attitudes. In this context, the students as prospective teachers are expected to transform STEM awareness into their classroom practices. Also in recent studies, researchers (Lim & Oh, 2015; Çınar, et al. 2016, Erdoğan & Çiftçi, 2017; Uysal & Cebesoy, 2020) stated that pre-service teachers gained STEM knowledge and awareness are willing to transfer their knowledge to classroom activities. In addition to the opinions of the students, the significant increase in the SPS test scores of the students shows the effectiveness of STEM activities. According to the question of "what skills are expected to develop in an individual who has received STEM education?", students stated that the activities could support to develop problem solving, creative and analytical thinking, and collaboration skills. Not only their expressions but also their post-test results show that the STEM activities carried out by simulation-based inquiry learning are effective in the development of SPS in students.

In the study, STEM activities were carried out through the inquiry learning strategy. In this context, they were contextualized with scientific inquiry and engineering design process. Students in inquiry learning conduct processes such as making observations, creating research questions, designing hypotheses, designing and executing experiments to test hypotheses, creating and interpreting data, creating models, communicating and forecasting (Pedaste et al., 2015). These processes are the ones that scientists use to conduct their research, and each process involves different skills. Moreover, the engineering design process includes skills such as problem solving, creativity, communication, collaboration. In the process of engineering design, students also use scientific process skills such as observing, evaluating, analyzing, hypothesizing, testing hypotheses, controlling variables, and measuring through the use of mathematical operations, and are thus expected to develop these skills (Strong, 2013). Students can able to solve real-world problems as they do using systematic thinking and analytical thinking skills of real engineers in STEM activities. Therefore, these activities provide students with the opportunity to develop both scientific and engineering process skills at the same time (Locke, 2009; Cayvaz, Akcay & Kapici, 2020). Therefore, STEM activities carried out in this study are effective in developing not only their engineering skills but also their SPS. This finding is consistent with the study of Gökbayrak and Karışan (2017) reporting that the STEM activities based on inquiry improve teacher candidates' scientific process skills. Similarly, recent researches (Siew, Amir & Chong, 2015; Bakırcı & Kutlu, 2018; Özbilen, 2018; Bektaş & Aslan, 2019) have introduced ideas that designing a model with interdisciplinary approach in science courses develops creativity, thinking skills and scientific process skills of teacher and teacher candidates. Pinelli and Haynie (2010) stated that engineering design could be useful for developing students' problem solving skills and working together as well as learning about scientific research and scientific method. They found that engineering design motivated students to apply their knowledge of science and mathematics, also developed skills related to reasoning, analysis, communication, organization, planning and creativity.

STEM integration to the laboratory course was carried out within the framework of the 5-step inquiry cycle proposed by Lim (2004). During the exploration phase of this cycle, students have done the necessary research to develop possible solutions to the engineering problem. In this context, they have hypothesized to solve the problem and to test their hypotheses, they have designed and conducted a virtual experiment using simulations. Thus, simulations provided a link between the solution of the engineering problem and the discovery. The students developed models for solving the problem by using simulation and tried to find the most suitable solution. In other words, simulations have been used in the exploration phase of scientific inquiry, in order to provide the necessary research and solution to the engineering design. In the workshop which was held to establish the connection between students' STEM concepts and earthquake engineering, researchers used simulation game to help students develop early warning systems and local emergency plans (Cavlazoğlu & Stuessy, 2016). It was also determined that teacher candidates generally have positive thoughts about the use of simulations in STEM education. The students stated that simulations were useful in designing, developing and experimenting engineering products. They emphasized that this situation gave them a significant advantage to design/redesign the experiments with the simulation models before creating the prototype. The students mentioned the importance of designing and performing virtual experiments to test their hypotheses in order to develop a solution to the problem. According to these findings, simulations can be used in STEM education for scientific inquiry and engineering design processes. This result is consistent with the findings of D'Angelo et al. (2014). In their meta-analysis study, the effect of the simulations on STEM education was investigated and the simulations were found to have a positive effect on achievement, scientific inquiry and reasoning skills and attitude dimensions. In our study, the use of simulations is found to be beneficial in process of designing and making experiments according to students' view. The process of designing and doing experiments is the most extensive inquiry phase that requires students to use many scientific process skills. In this phase, which starts with the hypothesis of solving the problem, students use scientific process skills such as identifying, changing and controlling variables, collecting data, converting tables and graphics, making decisions, using data and creating models. Therefore, in this study, students' qualifications of designing and performing virtual experiments with simulations show that these simulations are effective in the development of skills. In support of this finding, Huppert, Lomask and Lazarowitz (2002) found that simulations have a positive effect on the development of scientific process skills such as measurement, classification, graphical interpretation, data interpretation, control of variables and model design. Bell et al. (2010) highlight that students can develop hypotheses and test them more easily and quickly with simulations. They also stated that simulation software could provide data analysis such as tables, graphs and diagrams for experiments or modeling. In conclusion, considering results of this study and the studies in literature, the simulations are efficient in the realization of STEM activities and effective in the development of scientific process skills of students.

When considering the contribution of this study to the engineering skills of students, STEM activities carried out within the scope of laboratory practices provide students to gain meaningful laboratory experiences (Darrah et al., 2014). Scientific process skills and problem solving skills come at the top of the basic components that are expected to be formed by laboratory experiences (Hofstein & Lunetta, 2004). Therefore, according to educational approach, laboratory activities should allow students to develop scientific process skills, which are known as skills to learn scientific inquiry processes and to use these processes effectively. Also, inquiry-based laboratory activities provide students with the opportunity to acquire scientific thinking skills and learn how to test their ideas in class with their peers and expert science circles (Hofstein & Lunetta, 2004). Undoubtedly, the integration of the engineering design process with inquiry-based learning strategy that is so effective in laboratory activities will provide students with greater opportunities in terms of their gains. This study shows that students' search for real life problems with interdisciplinary approach in laboratory applications can make laboratory activities more meaningful and provide important opportunities in terms of skill development.

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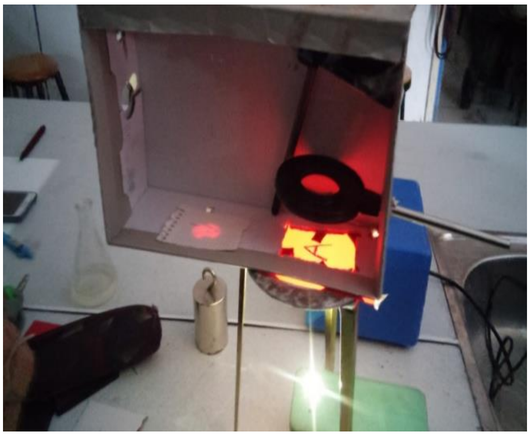
Appendix A: Student study examples


Activity 1.
Lighting design that reduces light pollution


Activity 2.
Periscope design


Activity 3.
A design that will reveal the secret of illusionists


Activity 4.
Projection design


Activity 5. A design for the use of lenses

Appendix B: Examples of students' simulation models