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The Impact of STEM-based Laboratory Activities on Pre-service Science Teachers' Competence Perceptions in 21st-Century Skills and STEM Awareness

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ABSTRACT This study aims to investigate the impact of laboratory activities prepared based on STEM-based learning on the competence perceptions in 21st-century skills (learning and innovation skills, life and career, information, media, and technology skills) and STEM awareness. The sample group consisted of 53 pre-service science teachers studying in year 2 of a public university. A quasi-experimental design formed the basis of this experimental study conducted as a quantitative research model. Pre-service teachers were randomly assigned, one to the experimental group (n=28) and the other to the control group (n=25). The experimental group was presented with laboratory activities based on STEM-based learning. In contrast, the control group had only laboratory activities (i.e., a group of students who did not conduct STEM-based laboratory activities). The measurement tools were the 21st Century Skills Competence Perception Scale (21st Century SCS) and the STEM Awareness Scale (SAS). All participants in the study expressed their agreement generally on the level of "I agree" for all three dimensions of the 21st Century SCS regarding STEM. As a result of the implementation, the SCS sub-dimension of "information, media and technology skills" and SAS skills of the experimental group students were higher than those of the students in the control group. It was found that the experimental group used the media and technology effectively and to use technology to access, analyze and share information. It was also thought that the individuals' problem-solving, critical, and high-level thinking skills developed more than the control group, thanks to the higher STEM awareness in the experimental group. Finally, some implications were proposed based on the research results from the STEM-based learning laboratory activities.

Keywords Competence perceptions in 21st-century skills, STEM awareness, Pre-service science teachers

1. INTRODUCTION

Due to the rapid change and advancements in science and technology, there is inevitably open and harmonious progress in every part of society, especially in education and teaching. In the 21st century, individuals have been expected to be able to find solutions to the problems they encounter through scientific approaches, as well as to have science process skills, think critically, design, and produce. Countries need to be strong in technology, conduct national research that will enable them to produce new products, and has well-trained personnel so that they can create international competitiveness and develop as a whole (Tekbıyık & Çakmakçı, 2018; Zollman, 2012). Initiatives such as the Society 5.0 and Industry 4.0 models have also prompted a change in the countries' education, and new approaches have been adopted in this regard.

In the same context, STEM (Science, Technology, Engineering, and Mathematics) based learning has entered many countries' curricula. This concept first emerged in the United States as a reform movement to improve education quality and boost engineering and entrepreneurship (Breiner, Harkness, Johnson & Koehler, 2012; Dugger, 2010). STEM presents an interdisciplinary approach instead of a single subject area by keeping the multidisciplinary approach in the foreground while a subject is being taught (Hom, 2014; Rennie, Venville & Wallace, 2012). STEM aims to train people in such a way as to enable them to adapt to scientific and technological advancements (Turkish Industry and Business Association [TUSIAD], 2017). STEM education provides teaching in school or out-of-school environments to a wide audience, from preschool to university students and professional

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teachers (Gonzalez & Kuenzi, 2012). Students raised in line with STEM-based learning can combine technology with everyday problems and develop relevant solutions with innovative approaches (Kennedy & Odell, 2014).

The key objective of STEM-based learning is to provide individuals with 21st-century skills (Bybee, 2010). These skills include performance-oriented features in which knowledge and skills are closely intertwined. They also refer to many capabilities such as creativity, cooperation, critical thinking, problem-solving, accessing reliable information, using the data, and being technology literate. Individuals who start life by gaining such skills are likely to be able to produce sustainably, solve problems effectively, and design in a qualified and efficient manner. Despite the lack of clear definitions or vocabulary for the mentioned skills, they are classified in different categories. By one exemplary category, these skills can be listed as Information, Media, and Technology (e.g., information and media literacy), Learning and Innovation (e.g., critical thinking, communication), and Life and Career (e.g., leadership and responsibility) skills (Partnership for 21st Century Learning [P21], 2019). As another example, Wagner (2008) classified these skills as leadership and teamwork, critical thinking and problem-solving, entrepreneurship, written and verbal communication, curiosity and imagination, accessing and analyzing information, and agility and adaptability. In today's conditions, it is expected that the 21st-century skills of teachers (pre-service and in-service teachers) need to be developed (Koçulu, Topçu & Çiftçi, 2022; Valtonen et al., 2021). The major expectations from the teachers are to combine their pedagogical practices with 21st-century skills (Fraillon, Ainley, Schulz, Friedman & Gebhardt, 2014; Sungur & Saylan Kırmızıgül, 2022).

Another important aspect of STEM-based learning is engineering. In its essence, the engineering approach includes the strategies and methods necessary to solve interdisciplinary and complex problems (Morgan, Moon & Barosso, 2013). With the application of the processes of the engineering approach, a research-based learning and teaching approach can be formed in educational environments (Rockland et al., 2010). Engineering-related careers are rapidly gaining importance, constituting an adequate workforce for future generations (Kennedy, Lee & Fontecchio, 2016). During the engineering design process, students can do experiments and research, use various applications, and learn from each other (Bender, 2017; Jolly, 2014). Although the design processes consist of different stages conducted by different researchers, the common stages can be identified as identifying the problem, developing possible solutions to the problem, analyzing and testing the solutions, repeating the solution processes, and presenting the ideas (Brunsell, 2012).

Science education aims to provide individuals with skills such as solving problems using scientific methods, conducting research and analysis, developing predictions, and being a reasonable observer. Many studies have revealed that practices based on STEM-based learning improve students by enabling them to gain these skills (Dejarnette, 2012; Deming & Norway, 2020; Fortus, Krajcik, Dershimer, Marx & Mamlok-Naaman, 2005; Hacıoğlu & Gülhan, 2021; Han, Kelley & Knowles, 2021; Kartini, Widodo, Winarno & Astuti, 2021; Koyunlu Ünlü, Z., & Dökme, 2022; Lavi, Tal & Dori, 2021; Morrison, 2006; Öztürk, 2018; Rohali, Qadar & Syam, 2023; Tekin, 2020; Thomazinho, L'Erario & Fabri, 2017; Zvoch, Letourneau & Spaniol-Mathews, 2023). STEM-based learning for science education is, therefore, regarded as really beneficial. Integrating engineering design processes with technology and mathematics and combining them with subject areas in science proves to make teaching easier and more permanent.

From this standpoint, enriching science education, which is intertwined with life, with STEM and design-based processes, is one of the expectations for contemporary education systems (Çavas, Bulut, Holbrook & Rannikmae, 2013; Haridza & Irving, 2017). In this sense, students can learn science and mathematics concepts, solve real-life problems, and develop many solution-oriented skills through engineering design processes (Purzer, Moore, Baker & Berland, 2018; Wendell, 2008). Engineers often use design loop steps while doing their work. These steps begin with realizing the problem and continue until the product is created (Çetin, Şatıroğlu & Yanık, 2018). Through engineering design skills, individuals gain the skills to apply engineering and science knowledge by adopting an interdisciplinary approach (Cunningham, 2017).

Considering the teacher training undergraduate programs updated by the Higher Education Council (YÖK) in our country, students studying the science teaching undergraduate programs are expected to have engineering and design skills (Yükseköğretim Kurulu, 2018). Having adopted the constructivist approach, studies aiming to improve the curricula, in general, began in 2005, followed by the revision of the Science and Technology curriculum in 2013 and the adoption of STEM-based learning in 2017. STEM education took an important place in the 2018 science course curriculum. Domain-specific skills were divided into science process skills, life skills, engineering, and design skills (Ministry of National Education [MEB], 2018). In this context, while teachers develop these skills, they take on the role of guides. At the same time, students are expected to be responsible for their learning and be able to make innovative discoveries, think with higher-order thinking skills, and develop designs. In a STEM environment, students are also expected to have high cooperation and communication skills. Moreover, following the educational vision for 2023, it was decided to establish workshops for developing design skills in educational institutions to cover all education levels, and pilot trials began in this regard (MEB, 2018).

The academic studies on the increasingly spreading STEM-based learning appear to have involved participants who are mostly primary, secondary, and high school students (Dedetürk, 2018; Rinke, Gladstone-Brown, Kinlaw & Cappiello, 2016; Tabar, 2018; Yılmaz, Gülgün & Çağlar, 2017). It is well-known that teachers affect students' success and play a leading role in them. From this point of view, it can be asserted that one of the cornerstones of STEM-based learning is the teachers (Bybee, 2013). The necessity of STEM education to reach the desired level and ensure that engineering integration can be done sufficiently reveal the need for well-trained teachers in these fields. It is also essential that such teachers be trained in a way that is intertwined with STEM-based learning during their university education before starting their professional life.

Research shows that engineering design should be integrated into courses for better science teaching (Cunningham & Kelly, 2017; Daugherty, 2012). Teachers should first be aware of what STEM is and then acquire the knowledge and skills required by the 21st century so that they can use STEM in their lessons (Rogers, Winship & Sun, 2016; Stohlmann, Roehrig, & Moore, 2014; Wilson, 2011). However, it is also known that teachers lack sufficient knowledge in this field with apparent information gaps (Adams, Miller, Saul & Pegg, 2014; Capraro, Capraro, Barraso & Morgan, 2016; Siew, Amir & Chong, 2015). It is expected and desired that STEM-based learning should be included in undergraduate courses, thereby raising awareness about STEM and enabling pre-service teachers to gain related skills before starting their professional life (Lin & Williams, 2017; Marulcu & Sungur, 2012; Özdemir, 2016; Sanders, 2009; Van Eck, Guy, Young, Winger & Brewster, 2015). Individuals with STEM awareness develop high-level thinking, problem-solving, and creativity skills. In addition, with STEM awareness, collaborative work, the ability to use science in daily life, interest, and attention to the lesson develop.

The present study examines the impact of the laboratory practices conducted based on STEM-based learning on pre-service science teachers' perceptions of competence in 21st-century skills and their awareness of STEM. The importance of the laboratory in the field of science is a well-known fact in the literature (Abrahams & Reiss, 2012; Martindill & Wilson, 2015). However, a commonly used "cookbook" laboratory procedure in science education restricts students' ability to acquire skills (Hofstein & Lunetta, 2004). Therefore, it is recommended to use practical approaches that will enable its development in a multidimensional way. STEM-based learning is one of the alternatives for effective laboratory studies in science teaching (Huri & Karpudewan, 2019; Batty & Reilly, 2022) and especially in physics concepts (Bao & Koenig, 2019; Eddy & Brownell, 2016; Stewart, 2013). In the relevant literature, there are several studies conducted with pre-service teachers regarding STEM awareness, which is one of these variables (Deveci, 2018; Gökbayrak, 2017; Hebebci & Usta, 2017; Karışan, Macalalag & Johnson, 2019; Tekerek & Karakaya, 2018; Üçüncüoğlu, 2018).

When some studies related to STEM awareness of pre-service teachers were summarized, Hebebci & Usta (2017) conducted a study in a relational survey model to examine the STEM awareness of 114 pre-service teachers studying at Year 1 and Year 2. The researchers reported that the results obtained from the awareness scale showed that despite the high levels of awareness of the pre-service teachers, they changed by gender. However, there was no significant difference according to the grade level. In a master's thesis, Gökbayrak (2017) examined the effects of STEM practices on pre-service science teachers' STEM awareness levels, their tendencies towards STEM teaching, and their science process skills. Based on the study results, the Laboratory Practices for Science Teaching-I course increased STEM awareness of preservice science teachers. Aslan-Tutak, Akaygün & Tezsezen (2017) examined the STEM awareness of 48 pre-service teachers studying in their final year of university after the 4-week collaborative STEM model the researchers had designed. At the end of the study, integrating STEM-based learning into the lessons and the relevant activities increased the teachers' awareness. As another example, Tekerek & Karakaya (2018) investigated the STEM awareness of 148 pre-service science teachers and reported no statistical significance in the STEM awareness of the participants in terms of gender, academic achievement, family income, and frequency of technology use. Ünlü-Koyunlu & Dere (2019) conducted a study with 384 pre-service preschool teachers concluding that the awareness of pre-service preschool teachers improved after STEM-based learning, and this STEM awareness favored pre-service male teachers. In a master's study on STEM awareness conducted by Baysal (2019) with the participation of 289 pre-service science teachers from two different universities, the researcher found no statistical significance in STEM awareness scale scores by gender and university variables. In another study, Karışan, Macalalag & Johnson (2019) examined 53 pre-service teachers who attended a 4-month STEM methods course. At the end of the method course, an improvement was observed in the pre-service teachers' awareness and their inclinations to teach STEM subjects. Şahin (2019) investigated the attitudes, awareness, and views of 34 pre-service science teachers who had prepared activities for STEM-based learning. As a result of the study, a statistically significant positive change was found in favor of the scores obtained in the post-test concerning the variables of attitude and awareness. In a thesis study, Şahiner (2020) examined not only the understanding of STEM but also the perceptions and views of 39 pre-service primary school teachers about engineering at the end of the engineering design period. The mixed model study was conducted with Year 2 pre-service teachers taking the Science and Technology Laboratory-I course. At the end of the 9-week procedure, a positive change was observed in the pre-service teachers' awareness, perception, and opinions towards STEM. Bulut-Atalar (2021) examined the effects of the educational exercise prepared on the STEM awareness, attitudes, and views of 94 pre-service science teachers. The results of the case study showed that the awareness and attitudes of the pre-service teachers towards STEM changed positively without any negative views developed towards the activities. In summary, the reviewed studies indicated that STEM-based learning practices increased STEM awareness, which was considered a variable.

n a similar sense, several studies examining pre-service teachers' perceptions of competence in 21st-century skills can be encountered in the literature (Jia, Oh, Sibuma, LaBanca & Lorentson, 2016; Murat, 2018; Yaşar, 2021). Kozikoğlu & Altunova (2018) conducted a study with 400 pre-service teachers and examined how their competence perceptions in 21st-century skills affect their lifelong learning skills. The researchers reported that the participants' scores in all sub-dimensions of the scale were at a "high" level, and their lifelong learning tendencies were at a "very high" level. Similarly, Murat (2018) conducted another study with 193 pre-service science teachers from five universities to focus on their competence perceptions in 21st-century skills and attitudes toward STEM. The quantitative study results revealed that pre-service teachers' competence perceptions in 21st-century skills appeared to be "high" for all sub-dimensions (learning and innovation skills, life and career skills, and information, media, and technology skills). Besides that, female pre-service teachers' perceptions were more positive in the sub-dimensions of "life and career skills" and "information, media, and technology skills". Erten (2020) examined the perceptions of students participating in pedagogical formation education toward 21st-century skills by gender, department, and knowledge of information and communication technologies. According to the study results, pre-service teachers had the skills included in the sub-dimensions of the 21st-century skills at a "sufficient" level. It was apparent that no statistical significance was present between the sub-dimensions of "information and communication technologies", "life and career skills", and the selected variables. In the sub-dimensions of "learning and innovation" and "information, media, and technology" skills, statistical significance was found in the relationships between the variables. Pre-service teachers appeared to focus on activities aimed at gaining "information, media, and technology skills" in practice. A master's thesis by Yaşar (2021) examined 50 science teachers' perceptions of competence in 21st-century skills and their STEM-related attitudes. As a result of that mixed-design study, it was found that teachers' self-efficacy perceptions were "high", with no statistical significance by gender and professional seniority. As another example, Karatepe (2021) examined the 21st-century competence perceptions of 208 pre-service teachers studying at a public university. According to the research results, the pre-service teachers' competence perceptions regarding 21st-century skills were found to be "high" for all sub-dimensions of the scale. In addition, participants' perceptions of 21st-century skills did not seem to differ by gender and year of study. Sütçü & Sütçü (2022) examined 347 pre-service teachers' perceptions of competence in 21st-century skills. At the end of the study, it was ascertained that the pre-service teachers had a "moderate" level perception of competence in the dimensions of "learning and innovation skills" and "life and career skills", despite having a "high" level perception in the dimension of "information, media and technology". Güllü & Akçay (2022) examined the relationship between 21st-century skills and STEM awareness of 242 pre-service primary school teachers in another study. The study's results revealed a positive and significant relationship between classroom teachers' 21st-century skills and their STEM awareness. In the relevant literature, some studies have examined the 21st-century skills of pre-service teachers or the relationship between such skills and certain variables such as attitude. This quantitative study discussed the participants' perceptions of competence in 21st-century skills and their awareness of STEM-based learning.

n light of the studies summarized above, this study aims to answer the following research questions:

1) How do laboratory activities based on STEM-based learning impact pre-service science teachers' perceptions of competence in 21st-century skills?
2) What is the impact of laboratory activities based on STEM-based learning on pre-service science teachers' awareness of STEM?

2. METHOD

2.1 Research Design

A quantitative research model was adopted, and experimental research was conducted to ascertain the effectiveness of the laboratory activities based on STEM-based learning. This study employed the quasi-experimental design with a control group as one of the experimental research models (McMillan & Schumacher, 2014). Figure 1 presents the work plan of the experimental design.

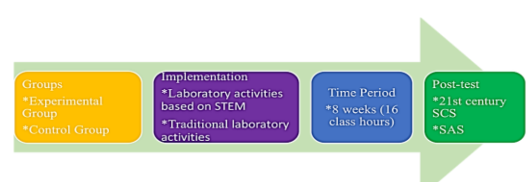

Figure 1 The experimental design of the research

The participants in the experimental group were instructed with laboratory activities based on STEM-based learning, while those in the control group were taught only laboratory activities. At the end of the study, the 21st Century Skills Competence Perception Scale (21st Century SCS) and STEM Awareness Scale (SAS) were distributed to both groups.

2.2 Participants

This study was conducted within the scope of the General Physics Laboratory-III course conducted in the fall semester of the 2021/22 academic year. The sample group consisted of 53 pre-service teachers studying in Year 2 of the Science Education Department of a public university. The laboratory course is usually given in 2 different classes. However, within the scope of this study, one of the classes was randomly determined as the experimental group (n=28, 26 females and three males) and the other as the control group (n=25, 18 females and seven males).

2.3 Data Collection Tools

21st Century Skills Competence Perception Scale for Pre-service Teachers (21st Century SCS)

The 42-item scale was developed by Anagün, Atalay, Kilic, & Yasar (2016) to determine the possible perceptions regarding 21st-century skills. The adopting scale consisted of 3 sub-factors (1. Learning and innovation skills, 2. Life and career skills, and 3. Information, media, and technology skills). The scale was prepared in a 5-point Likert type, including the levels of Always (5), Often (4), Sometimes (3), Rarely (2), and Never (1). The reliability coefficient of the scale was calculated as .889, and Cronbach's alpha values based on sub-factors were calculated as .845, .826, and .810, respectively. The coefficients of each sub-factor are over 0.70, indicating that the scale is reliable. When the total correlation values of the items in the scale are examined, each item is above r=.30. This is proof of the high validity of the items. Some sample items of the scale are presented below:

"I can develop original ideas to solve the problems I encounter."

"I use social networks to share information."

STEM Awareness Scale (SAS)

The 17-item scale was developed by Buyruk & Korkmaz (2016) to reveal students' awareness of STEM-based learning. The reliability coefficient of the adopting scale was found to be .927. Moreover, each item is above r=.30. So validity and reliability are provided. The scale was a 5-point Likert type, consisting of grading from Strongly Agree (5), Agree (4), Undecided (3), Disagree (2), to Strongly Disagree (1). Two sample items have been described below:

"STEM, which stands for an educational approach combining Science, Technology, Mathematics, and Engineering, includes four basic disciplines."

"The aim of STEM-based learning is to learn by establishing relationships between disciplines with a holistic approach."

2.4 Implementation

Implementation in the Experimental Group

Before starting the procedure, all pre-service teachers were informed about the basic theoretical information about mirrors and lenses and showed in detail their image formation and features. With this experience, the pre-service teachers were divided into six groups in a way that would be heterogeneous within the group and homogeneous between the groups, taking into account the preliminary knowledge levels of the pre-service teachers. Each group consisted of an average of five pre-service teachers. The group members were asked to choose a chairman, a vice-chairman, a spokesperson, a graphic designer, and a reporter and to find a name for their group to ensure that all group members could actively participate. After the preparation stages were completed, STEM-based learning was introduced to the participants in the experimental group by the researchers in the classroom for 2-course hours, and some additional informational instructions for STEM were distributed. On the completion of the laboratory activities based on STEM-based learning, which lasted 14-course hours (7 weeks), post-tests (2-course hours) were administered. During the research process, the activities presented in Figure 2 were designed.

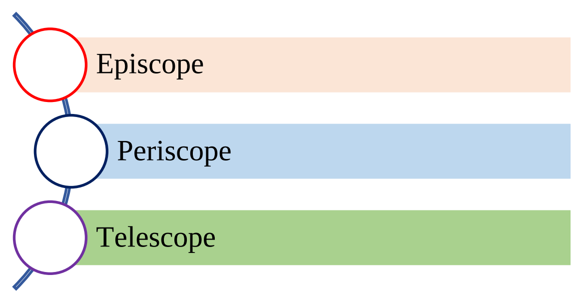

Figure 2 Activities in experimental group

In the experimental group, pre-service teachers applied which type of mirror and lens to use and how they would be used by designing an episcope, periscope, and telescope. Pre-service teachers' laboratory activities based on STEM-based learning were conducted concerning the engineering design process steps, as suggested by Hynes et al. (2011). In addition, the researchers readily provided the problem situations to the pre-service teachers. The steps to STEM-based learning have been presented as follows:

- Identifying the needs regarding the problem and developing possible solutions,
- Selecting the solution proposal that meets the limitation and success criteria the most among the solution proposals,
- Making prototypes of designs to visualize and present the developed designs, reveal their details besides advancing the designs,

- Testing and evaluating the developed prototypes, taking into account the success criteria and limitations,
- Receiving feedback upon presenting the solution to other pre-service teachers and researchers,
- Making revision studies on prototypes in line with the evaluations and feedback received from within the group and from others,
- After the revision stage, the necessary measures were taken, and the steps of finalizing the decision were carried out meticulously based on the consideration that the final products were developed sufficiently.

The participants were provided with the necessary materials from the available laboratory, and the researchers guided and helped them to obtain the materials that were not accessible in the laboratory. During the process, a WhatsApp group was created to communicate with each other and the researchers whenever they wanted, ensuring that the pre-service teachers constantly exchanged ideas. Along with the in-depth explanation regarding STEM-based learning and the conduct of the post-tests in the end, the study was completed in 16-course hours (8 weeks). Figure 3 illustrates the photographs of pre-service teachers performing at the different stages of the procedure.

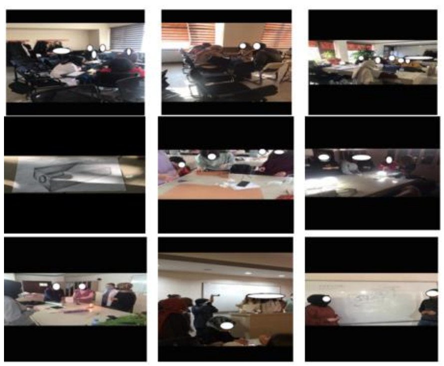

Figure 3 Some photos of students during experimental studies

In Figure 3, first line, there were visuals related to the determination of the needs for the problem, the development of possible solution suggestions, the selection of the limitation, and the solution proposal. In the second line, there were visuals related to making prototypes of designs and testing and evaluation of developed prototypes by considering success criteria and limitations. In the third line, visuals were related to the solution being presented to other teacher candidates and researchers, receiving feedback and revising it.

Implementation in the control group

Before the implementation, all participants were given some basic theoretical information about mirrors and lenses and were shown in detail the image formation and features of mirrors and lenses, after which those in the control group were divided into seven groups of three or four on average, taking into account their prior knowledge levels, in a way that they would be heterogeneous within the group and homogeneous between the groups. Before proceeding to the activities, the researchers provided the pre-service teachers with preliminary information about the activities to be carried out in two-course hours. Each action, which took seven weeks, lasted a week. The participants were supplied with the necessary materials for the activities, which were ensured to be performed by following the instructions in the laboratory book. The researchers aimed to help the pre-service teachers in the activities by visiting the groups and ensuring that the actions were in-depth and comprehended by asking the participants several questions to eliminate anything unclear. The activities given in Figure 4 were applied throughout the process.

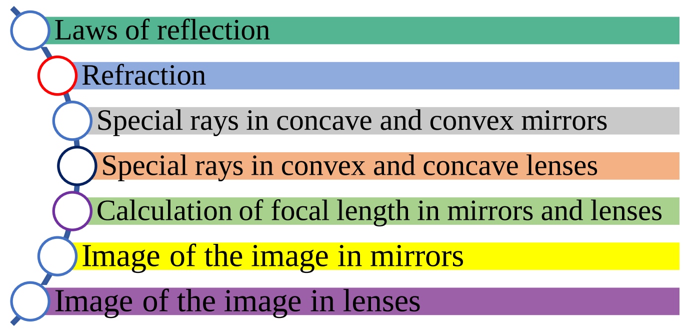

Figure 4 Activities included in the control group

2.5. Data Analysis

One-Way Multivariate Analysis of Variance (One-Way MANOVA) was used to determine if there was a difference in the sub-dimensions of 21st-century SCS between the experimental and control groups, and an independent samples t-test was performed to ascertain whether there was a difference in SAS. SPSS 21 package program was used for the analyses. Prerequisite assumptions must be checked before performing the statistical analyses for administering the parametric tests (Can, 2013; Pallant, 2016). In the data analysis, therefore, the researcher first tested whether or not the assumptions were met for the single-factor MANOVA and independent samples t-test analysis. The relevant assumptions are given below:

One-factor MANOVA assumptions

1st Assumption: The Kurtosis-Skewness values indicated that the pre-test data showed univariate and multivariate normal distribution (Table 1). In addition, by calculating Mahalanobis' values, assumptions were confirmed since no extreme importance disrupted the multivariate normality and exceeded the multivariate critical value.

Table 1 Normality test

Dimension	Kurtosis	Kurtosis S.H.	Skewness	Skewness S.H.
Learning and innovation skills	0.295	0.327	-0.177	0.644

Table 1 Normality test *(Continued)*

Dimension	Kurtosis	Kurtosis S.H.	Skewness	Skewness S.H.
Life and career skills	-0.915	0.327	0.668	0.644
Information, media and technology skills	-1.466	0.327	1.748	0.644

2nd Assumption: As there was a significant and positive relationship between the dependent variables, a reasonable correlation assumption was confirmed (r=0.56 p<0.01; r=0.32 p<0.05) (Table 2). The correlation coefficient remaining below 0.9 showed that there was no multicollinearity between the data.

Table 2 Correlation values

		Learning and innovation skills	Life and career skills	Information, media and technology skills
Learning and innovation skills	Pearson Correlation	1	0.560	0.318
	Sig. (2-tailed)		0.000	0.021
	N	53	53	53
Life and career skills	Pearson Correlation	0.560**	1	0.661
	Sig. (2-tailed)	0.000		0.000
	N	53	53	53
Information, media and technology skills	Pearson Correlation	0.318*	0.661	1
	Sig. (2-tailed)	0.021	0.000	
	N	53	53	53

3rd Assumption: Box Test, showing that there was no significant difference between the covariance matrices. Here, the assumption was confirmed since the p-value (p=0.514) was p>0.05 (Table 3).

Table 3 Box's test of equality of covariance matrices

	Value
Box's M	5.597
F	0.873
df1	6
df2	18167.377
Sig.	0.514

4th Assumption: Just like in the Box test, the assumption that there was no statistical significance between error variances was confirmed for the MANOVA test. For this, the Levene's Test revealed that the error variances between learning and innovation scores (p=0.66, p>0.05), life and career scores (p=0.32, p>0.05), information, media, and technology (p=0.18, p>0.05) scores could be considered equal (Table 4).

Table 4 Levene test

	F	df1	df2	Sig.
Learning and innovation skills	0.200	1	51	0.657
Life and career skills	1.000	1	51	0.322
Information, media and technology skills	1.865	1	51	0.178

Independent Samples t-test Assumptions

1st Assumption: The Kurtosis-Skewness values showed that the dependent variable showed a normal distribution in the groups (Table 5).

Table 5 Normality test

Scale	Kurtosis	Kurtosis S.H.	Skewness	Skewness S.H.
STEM Awareness	1.966	0.644	0.117	0.327

2nd Assumption: Levene's test was used to ascertain whether or not the variances showed a homogeneous distribution. Since the p-value in Levene's test (p=0.056) was p>0.05, the assumption of homogeneity of variances was confirmed (Table 6).

Table 6 Levene test

	F	p
Awareness Scores	8.763	0.056

3. RESULT AND DISCUSSION

3.1 Results on the Pre-service Teachers' Competence Perceptions in 21st-Century Skills about the STEM Based Learning

Table 7 presents the results of one-way MANOVA conducted to reveal whether STEM-based learning had a clear impact on the pre-service teachers in the experimental and control groups as regards their competence perceptions in 21st-century skills.

Table 7 The results of one-way MANOVA

Effect	Wilks' Lambda	F	p	η^2
Group	0.923	1.366	0.264	0.077

According to the results of one-factor MANOVA (Table 7), no statistically significant difference was observed between the experimental and control groups in terms of their competence perceptions in 21st-century skills [$F(3-49) = 1.366$, $p>0.05$ Wilks' $\wedge = 0.923$, partial $\eta^2 = 0.077$]. In other words, there is no significant difference in the 21st-century skills scale, but when the sub-dimensions are examined, it is seen that there is a significant difference in the 3rd dimension. Table 8 shows the one-way ANOVA results for each dependent variable

Table 8 One-way ANOVA results for each dependent variable

	Group	N	X	ss	sd	F	p	n²
Learning and innovation skills	Experimental	28	3.75	0.093	3-49	0.534	0.468	0.010
	Control	25	3.65	0.099				
Life and career skills	Experimental	28	4.08	0.102	3-49	2.082	0.155	0.039
	Control	25	3.86	0.107				
Information, media and technology skills	Experimental	28	4.29	0.172	3-49	4.241	0.045	0.077
	Control	25	3.78	0.182				

(learning and innovation skills, life and career skills, information, media, and technology).

As can be seen in Table 8, no significant difference was revealed between the groups in terms of their learning and innovation skills [(3−49) = 0.534, $p>0.05$], and life and career skills [(3−49) = 2.082, $p>0.05$]. However, a significant difference was observed in favor of the experimental group [(3−49) = 4.241, $p<0.05$] in information, media, and technology skills.

Table 8 further shows that the participants' mean score in learning and innovation skills on the 21st century SCS about STEM-based learning was 3.75 (X=3.70) in the experimental group and 3.65 (X=3.65) in the control group. On the other hand, the mean score for life and career skills in the experimental group was 4.08 (X=4.08) and 3.86 (X=3.86) in the control group, along with the mean score for information, media, and technology skills being 4.29 (X=4.29) in the experimental group and 3.78 (X=3.78) in the control group. Since the range of arithmetic averages was found to be between 3.40 and 4.19 (frequently) in the range of 5 columns and four rows (Arslan, 2008), it appeared that all participants tended to express their opinion at the level of "frequently/I agree" in all three dimensions. However, the mean scores in the experimental group in all three sub-dimensions were higher than in the control group.

3.2 Results of the STEM Awareness Scale

Table 9 presents the independent groups' t-test and descriptive statistical analysis results to determine whether or not STEM-based learning brings about a remarkable impact on students' STEM awareness scores of the participants in the experimental and control groups.

Table 9 SAS experimental and control groups independent groups t-test results

Group	N	X	ss	df	t	p
Experimental	28	3.53	0.37	51	3.009	0.006
Control	25	3.06	0.71			

As can be seen from the analysis results in Table 9, the statistical significance between the mean scores of the experimental and control groups in the SAS was in favor of the experimental group (t(51)=3.009; p<0.05).

The mean SAS score of the participants in the study for STEM-based learning was found to be 3.53 (X=3.53) in the experimental group and 3.06 (X=3.06) in the control group. In this connection, the pre-service teachers in the experimental group generally expressed their opinions at the level of "often/agree", and those in the control group at the level of "undecided/sometimes".

This study investigated the impact of laboratory activities prepared based on STEM-based learning on pre-service teachers' competence perceptions in 21st-century skills and their awareness of STEM. The extent of competence perceptions in 21st-century skills consists of sub-dimensions such as learning and innovation, life and career skills, and information, media, and technology skills. In contrast, STEM awareness does not have any sub-dimensions. When the 21st-century SCS was examined in general, it was apparent that the mean scores of the experimental and control groups were at the level of "agree/often". Such results seem compatible with similar studies in the relevant literature (Erten, 2020; Karatepe, 2021; Keskin & Yazar, 2015; Murat, 2018; Yaşar, 2021). Furthermore, when evaluated in terms of SAS results, it can also be asserted that the results of the present study support the results of similar studies (Bulut-Atalar, 2021; Gökbayrak, 2017; Hebebci & Usta, 2017; Karışan, Macalalag & Johnson, 2019; Şahiner, 2020; Ünlü-Koyunlu & Dere, 2019).

A detailed evaluation of our current study revealed that laboratory practice based on STEM-based learning did not significantly impact 21st-century skills. However, when the sub-dimensions of the 21st century SCS were evaluated separately, it appeared that the relevant activities were not influential about "learning and innovation skills" and "life and career skills". Still, it impacted the "information, media, and technology skills".

Being one of the sub-dimensions of 21st-century SCS, learning and innovation skills enable individuals to develop original ideas, use various thinking techniques, try different solutions and perspectives in problem-solving, use their imaginations, and establish a relationship between knowledge and argument by questioning claims. In the present study, the researchers provided the participants with the tools to create a product at the end of the engineering design process. They assigned them particular topics for teaching optics as a subject matter. In addition, specific information about the optics they were supposed to use in their designs had been presented as a problem statement. In other words, the participants did not have to make extra efforts to create their original ideas, use their imagination to solve the problem, or analyze relationships. Therefore, this could be why there was no difference between the pre-service teachers in the experimental and control groups in terms of "learning and innovation skills".

Another sub-dimension -life and career skills- generally addresses the issues of effective communication, cooperation, adapting to different roles and new situations, and respecting different people and cultures. In this study, it can be argued that the reason why the technique applied in the laboratory process based on STEM-based learning, which has been explained in detail in the method section, did not contribute to the participants' "life and career skills" is that the telescope, episcope, and periscope designs have long been designed by many others before and that the pre-service teachers can easily access these designs through media tools. The participants could take active roles in group work and discuss with each other, communicate and cooperate, and easily access existing designs via the Internet without doing many different research and studies. Due to this, there was no opportunity for them to develop their "life and career skills" during the application process, which explains why there was no statistical significance compared to the control group.

The last sub-dimension of the 21st century SCS, namely information, media, and technology skills, includes those skills to use the media and technology effectively and to use technology to access, analyze and share information. The present study found that the experimental participants' opportunity able to access the necessary information about the product to be made, the internal structure of the tools, and the materials needed for a design using media tools and technology may have had a positive contribution to the development of their "information, media, and technology skills", which is the third sub-dimension of the 21st century SCS, compared to the control group. In addition, the participants may have implicitly paid attention to the benefit of technology during the practice based on STEM-based learning. In the study of Erten (2019), the researcher emphasized that studies on "information, media, and technology skills" should be prioritized so that pre-service teachers can develop 21st-century skills. Research demonstrates that pre-service teachers consider themselves insufficient in information, media, and technology skills (Bozkurt, 2020; Çakır & Güngör, 2017). From this point of view, it can be argued that with the experimental procedure in our study, such lack of knowledge in the literature was eliminated.

STEM awareness examined in this study also created a statistical significance between the pre-service teachers in the experimental and control groups in favor of the experimental group. In a general sense, STEM awareness attracts the attention and interest of individuals and develops their problem-solving, critical, and higher-order thinking skills. It offers the opportunity for collaborative work and establishing relationships between disciplines. An increase in an individual's awareness level means an increase in the state of being conscious of oneself and the environment (Çevik, 2017). STEM activities in similar studies conducted in line with our findings have appeared to raise awareness of pre-service science teachers towards STEM.

Similarly, as a result of the study, which examined the STEM-oriented laboratory practices and the awareness of prospective science teachers about STEM, Üçüncüoğlu (2018) found that individuals' awareness and competencies about STEM improved thanks to STEM-based learning. The study prepared by Duygu (2018) aimed to examine the effect of STEM-based learning carried out in a simulation-based inquiry learning environment on the STEM awareness of pre-service science teachers. It has been determined that it positively affects STEM awareness and provides improvement. In this manner, it helps pre-service teachers develop their creativity and develop original ideas and solutions. It also encourages pre-service teachers and contributes to integrating four basic disciplines (science, technology, engineering, and mathematics). Moreover, it helps pre-service science teachers be more active, enhancing their interest and attention.

4. CONCLUSION

This study revealed the perceptions of competence in 21st-century skills and their awareness of STEM of pre-service teachers towards the laboratory practices conducted based on STEM-based learning. The first result obtained from the research was that STEM-based learning did not significantly improve pre-service teachers' levels of learning and innovation skills and life and career skills. Still, it provided improvement in information, media, and technology skills. And the second result was a significant change in students' STEM awareness thanks to STEM-based learning.

It can be suggested that information about the product to be designed by the learner should not be explicitly given beforehand to achieve positive and statistical significance in all sub-dimensions of 21st-century skills. Instead, by applying integrated STEM-based learning with methods such as Argumentation-Based Science Learning (ABSL), Problem-Based Learning (PBL), and Context-Based Learning (CBL), etc., learners can research and ultimately decide what to do. Also, in the engineering design process, interdisciplinary directions can be presented in a way that will require effort for learners to reach the necessary information.

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