ORIGINAL ARTICLE

A Technology-Based Project with a Study that Simultaneously Evaluates STEM Awareness, STEM Self-Efficacy Beliefs, and 21st Century Skills

Necla Dönmez Usta, Neslihan Ültay

Giresun University, Giresun, Turkey

***Abstract**: This study seeks to determine the pre-service science teachers' STEM self-efficacy beliefs, STEM awareness, and 21st century skills at the beginning and end of a technology-based project. 28 pre-service science teachers, all aged 20-24, were included in the study. They were the 3rd or 4th grade pre-service science teachers studying at 13 universities in Turkey. From a quantitative perspective, three different data collection tools were included in the study. The first of all, the "STEM Awareness Scale", the second data collection tool was "The Self-Efficacy Scale Related to STEM Practice", the third data collection tool was the "Multidimensional 21st Century Skills Scale" and from a qualitative perspective a survey form including 7 open-ended questions were administered. This study was found to have contributed positively to STEM self-efficacy beliefs and 21st century abilities, and it continued to contribute positively to STEM awareness, but not statistically. It can be suggested that such activities must be designed and organized not only for pre-service teachers but also for 21st century learners such as teachers, all faculty members working at the university, and all students, etc.*

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***About the Author**: Necla Dönmez Usta, Associate Professor Dr., Department of Computer Education and Instructional Technology, Faculty of Education, Giresun University, Giresun, Turkey, E-mail: necla.donmezusta@giresun.edu.tr, ORCID: https://orcid.org/0000-0002-8075-7446*

Neslihan Ültay, Professor Dr., Department of Elementary Education, Faculty of Education, Giresun University, Giresun, Turkey, E-mail: neslihanultay@gmail.com. ORCID: https://orcid.org/0000-0002-9783-0486

***Correspondence to**: Necla Dönmez Usta at Faculty of Education, Giresun University in Türkiye.*

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***Ethical Declarations:** All procedures performed in this study followed the ethical standards of the Department of Health Standards on Human Research (DOH/QD/SD/HSR/0.9) and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The first author is the project organizer and applied to TÜBİTAK by receiving an official letter signed by the Vice Rector of Giresun University. The project was accepted by TÜBİTAK and announced to universities across Türkiye. Participants participated on a voluntary basis and were selected according to certain criteria. In addition, both written and verbal participation consent was obtained from the participants. The project and the selection criteria of the participants are available on the Giresun University website (http://etkilesimlimateryal.giresun.edu.tr). This statement is an ethical rule that must be followed in order to carry out the event.*

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***AI Declaration**: The author affirms that artificial intelligence did not contribute to the process of preparing the work.*

Introduction

THERE are a lot of researches about STEM and a lot of explanations how STEM boomed in education. But mostly common point is that STEM education is effective in teaching STEM disciplines and positively affects students' future career choices. STEM education is an integrated approach to enable students to develop creative problem-solving techniques, and the development of future innovators (Er & Başeğmez, 2020).

STEM education aims to provide students with environments in which they can gain experience and prepare them to become future scientists, technologists, innovators, or engineers because STEM education focuses on solving problems using real-world examples rather than traditional educational programs (Breiner et al., 2012). However, it is widely accepted by several developed countries that STEM has a lot of positive impacts on education systems all over the world, but at this point, a serious problem has arisen because the teachers who will implement STEM in their classrooms are unqualified and insufficiently trained for STEM education (Nowikowski, 2017). This problem forces the education system to change teacher preparatory programs. In Turkey, some universities add STEM courses to their teaching programs as obligatory or elective lessons in order to overcome the problem mentioned above. As in this project, some initiatives can be taken by the researchers, such as scientific projects.

Implementing STEM education is a good starting point to gain 21st century skills because STEM education does not provide only effective teaching but also has an important role in helping individuals acquire 21st century skills (Capraro et al., 2013). According to Çeliker (2000) the combination of STEM education and 21st century skills are equally critical. Teachers' knowledge and expertise in a single field are insufficient to raise individuals suitable for countries' 21st century skills without interdisciplinary work (Çorlu et al., 2014). STEM education prepares students for the 21st century by providing them with the necessary skills (Tsupros et al., 2009). It promotes the development of 21st century skills such as cooperation, questioning, critical thinking, and problem solving (Sanders, 2009; Khalil & Osman, 2017).

There a lot of skill lists explaining what the 21st century skills are by different organizations. The Partnership for the 21st century skills (P21, 2002), which is one of the organizations, listed the 21st century skills as learning and innovation skills, knowledge, media and technology skills, and life and career skills (Kyllonen, 2012). Individuals who have the 21st century skills should be creative, innovative, solution-oriented, highly motivated, strong in communication, and technology lover, etc. (Aydeniz, 2017; Ültay et al., 2021).

According to Rotherham and Willingham (2009), these skills such as problem solving and critical thinking, which enable the solution of many problems, are as old as human history and they should not be referred to as 21st century skills. However, the meaning attributed to it has changed. In order to raise individuals who can keep up with the times, we should organize effective teaching programs that can provide them with these skills. Effective programs emphasized sustained or sequential activities rather than unstructured, one-time opportunities; relied on active student participation; emphasized personal and social skills by allocating time specifically to develop those skills; and explicitly identified which skills they developed (Kyllonen, 2012). In the new world order, teamwork skills, self-reflection or time management are considered more important than knowing mathematics or science. STEM education as mentioned above can provide good opportunities for students to gain 21st century skills (Bybee, 2010).

For teachers and even pre-service teachers, teaching competence is crucial to the implementation and quality of STEM education in schools and is influenced by teachers' learning experiences during preparatory programs (Song & Zhou, 2021). Preparatory programs or in other words internship programs can provide different teaching experiences for pre-service teachers to gain teaching competency and self-efficacy in a real classroom. Teachers of the real classrooms can also gain benefits from the implementation of pre-service teachers in their classrooms through these preparatory programs. Teachers, for example, may learn new teaching approaches, models, and so on from pre-service teachers' implementations. By the way, teaching competency and self-efficacy for pre-service teachers will be developed. Teaching competence is also directly related to teachers' self-efficacy. At this point, it can be talked about a multi-faceted interaction in between the teacher and the pre-service teachers and also in between teaching competence and self-efficacy of the pre-service teachers.

According to Bandura (1994), an advocate of Social Cognitive Theory, self-efficacy is a person's ability to do a job. Bandura referred to one's personal judgments of one's abilities to organize and execute actions to achieve set goals. Bandura (2006) suggested four sources, including performance accomplishments, vicarious experience, social persuasion, and psychological responses, which either strengthen or weaken self-efficacy. According to Rockinson-Szapkiw et al. (2022), while performance accomplishment is related to one's experience in performing a specific task, vicarious learning refers to experiences and requires the individual to observe another person performing the task. For this reason, both pre-service teachers and teachers have experienced both of these aspects (performance accomplishments and vicarious experience). When pre-service teachers or teachers accomplish a task successfully, their self-efficacy increases, if do not accomplish, then it lowers. In this project and other STEM classes because direct feedback is provided, pre-service teachers' self-efficacy is expected to evolve (Stewart et al., 2020).

Self-efficacy is defined as a person's own belief about being successful or not on a task (Salar, 2021). Self-efficacy has emerged as a key factor in academic motivation, goal setting, and performance (Richardson et al., 2012). Self-efficacy is necessary for the effective use of self-regulation skills to achieve mastery and plays a causal role in the development and employment of academic competences (Schunk & Pajares, 2007). Also, self-efficacy skill significantly affects a person's career choices in the future (Stewart et al., 2020). Dorssen et al. (2006) discovered that informal STEM activities are one of the most promising ways to encourage young people to reconsider career paths that they had previously dismissed due to faulty beliefs. As a result, as happened in this project, students benefit from being exposed to informal opportunities that help them form accurate perceptions of STEM careers (Blotnicky et al., 2018). Accurate STEM perceptions affect and shape STEM awareness in a good direction.

Individuals with a high level of STEM awareness are those who are concerned about STEM education. It is possible that these individuals will shape their own attitudes and behaviors in response to the STEM approach over time (Çetin, 2021). According to Şahin's study (2019), it has been reported that pre-service science teachers who participate in STEM activities become more aware of and have a positive attitude toward STEM disciplines. Salar (2021) and Nadelson and Seifert (2013) stated that STEM awareness is a key factor for a good STEM teaching experience. According to Edwards and Loveridge (2011), teachers frequently fail to recognize available learning opportunities due to a lack of pedagogical awareness of how to teach science.

The Research Problem

This study is a part of an online project supported by Scientific and Technological Research Institution of Turkey (TUBITAK). Within the scope of this study, STEM awareness, STEM self-efficacy beliefs and 21st century skills of pre-service science teachers were tried to be determined and answers were sought for the following sub-problems:

- Is there a significant difference between the pre and post-test scores of pre-service science teachers on STEM awareness levels, STEM self-efficacy beliefs, and 21st century skills?
- What are the opinions of pre-service science teachers about 21st century skills after receiving STEM training?

Methodology

The study can be described as a case study with a more quantitative perspective, as it tries to measure pre-service teachers' STEM self-efficacy belief, STEM awareness, and 21st century skills at the beginning and end of the STEM education part of the project. The study's qualitative dimension was to seek the thoughts of pre-service science teachers' 21st century skills by a survey form. As it is known, case studies focus on a group's characteristics, and in this study, pre-service science teachers participated in an online project funded by TUBITAK in Turkey. The project, which was called "Designing and Developing Interactive Teaching Materials Suitable for the New World Order," was a short-term project and lasted for four weeks in 2021-2022 spring semesters.

In the first 5 days of the project, training on teaching methods and techniques and digital applications was given every day. For example, each day, one modern teaching method and one digital applications (Kotobee™, Educaplay™, Thinglink™, etc.) were mentioned, and sample teaching materials were shown and discussed. To give an example, on the first day of the project, STEM was presented online by ZOOM™ and some example teaching materials were shown to the pre-service teachers by the second researcher. On the same day, the first researcher presented Kotobee™, which was a program allowing pre-service teachers to design digital interactive teaching materials and interactive e-books. At the end of each day, pre-service teachers designed and developed digital interactive teaching materials in which they used STEM, Kotobee™, or other approaches and digital applications. This teaching experience was carried out on the day that STEM was taught. It is good to note that all of these pre-service science teachers knew the STEM teaching methods in their undergraduate programs at their universities before attending this project. In addition, they have just learned the Kotobee™ application and received feedback from the field expert for the relevant application throughout the week. For three weeks, the pre-service science teachers and the researchers engaged in an interactive process of receiving this input. During these three weeks, pre-service teachers revised the interactive lesson plans they had created in accordance with the researchers' recommendations and displayed the final product in the exhibition. Three weeks following the theoretical applications, the procedure came to a close with the exhibition and administration of post tests.

After the project is accepted by TUBITAK, an announcement is made through an open call so that 3rd and 4th grade students of science teaching departments in all universities in Turkey can apply. Purposive sampling was used to select participants for the study. The sampling was created by including people, events, objects, or situations with qualifications determined in relation to the problem. Because certain criteria were used to choose which pre-service instructors would participate in the study, criterion-based sampling was determined to be appropriate (Büyüköztürk et

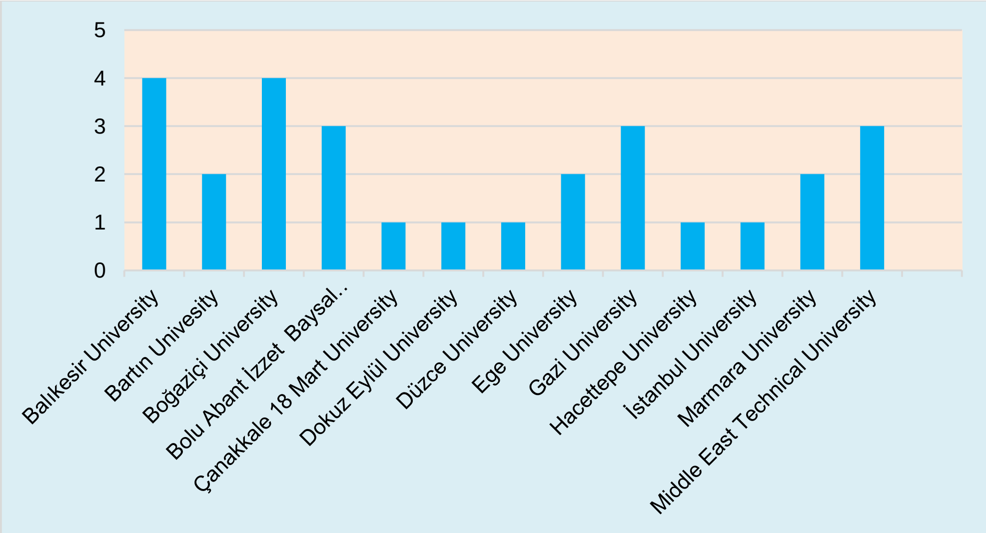

Figure 1. The Number of Participants and the Distribution of the Universities.

al., 2015). In the determination of the participants, applications were received through the website (URL-1) opened to the project in the 2021-2022 academic year. Among the many applications made, 30 participants who best met the application criteria were selected as permanent and 15 participants as substitutes. Controls were provided by making technical trial applications of the computer hardware of the determined participants. Participants who could not provide sufficient technical equipment for the project were excluded and technical trial applications were carried out with the designated reserve participants. As a result of these practices, 30 main participants were determined. 28 of the 30 main participants participated in the implementation process full-time, but 2 participants could not participate full-time due to various reasons. 28 pre-service science teachers, all of them were girls (by chance) aged 20-24, were included in the study.

They were the 3^{rd} or 4^{th} grade pre-service science teachers studying at different universities in Turkey in the academic year mentioned before. The number of participants and the distribution of the universities they studied were presented in **Figure 1** below.

Data Collection Tools

From a quantitative perspective, three different data collection tools were included in the study. The first of all, the "STEM Awareness Scale" (SAS), was a Likert type questionnaire and was developed by Buyruk and Korkmaz

(2016). SAS, which consisted of 17 items, was used to determine pre-service science teachers' STEM awareness levels. The first 12 items were in the "positive view" and the last 5 items were in the "negative view" sub-dimension, so the negative ones were reverse coded and included in the analysis. For the positive view "STEM gives students high-level thinking skills" and "STEM education enhances collaborative work in students" can be given as examples and for the negative view "STEM applications distract students from the lesson" and "Practicing STEM activities wastes time" can be given as examples.

The second data collection tool was "The Self-Efficacy Scale Related to STEM Practice" (SES) developed by Yaman et al. (2018) and was used to determine self-efficacy beliefs related to STEM practice of pre-service teachers. The SES consisted of 18 likert type items. "I am academically proficient in the science process skills required when designing a STEM activity", "I can easily interpret the results of STEM-related activities" and "I can determine the objectives to be gained in STEM activities in accordance with the characteristics of the student and the environment" can be given as example items for SES.

The third data collection tool was the "Multidimensional 21st Century Skills Scale" (MCSS) which was a Likert type scale, developed by Çevik and Şenturk (2019) and was used to determine the pre-service science teachers' 21st century skills. The scale was developed for people/students between the ages of 15-25 and consisted of 41 items. Because 16, 17, 18, 19, 20, 21, and 35th items were negative, they were coded reversely. "I get different information and ideas by following various sources", "I think about the needs that may arise in the world in the future and I do research about it" and "I do not like people who criticize me" can be given as example items for the MCSS.

From a qualitative perspective, a survey form was used to collect data about the pre-service science teachers' 21st century skills. In the survey form, 7 open-ended questions about 21st century skills were asked to the pre-service science teachers. Firstly, the draft version of the questions was created based on the literature. Secondly, expert opinion was obtained from two education experts, one in science education, and the other in chemistry education, leading to the draft revision. The researchers made an online pre-application, as a pilot scheme, to 4 pre-service science teachers, and were not found any problems with the clarity and responsiveness of the form. Finally, the survey form was finalized. This form was created on Google forms, the survey administration software offered by Google.

Implementation Process

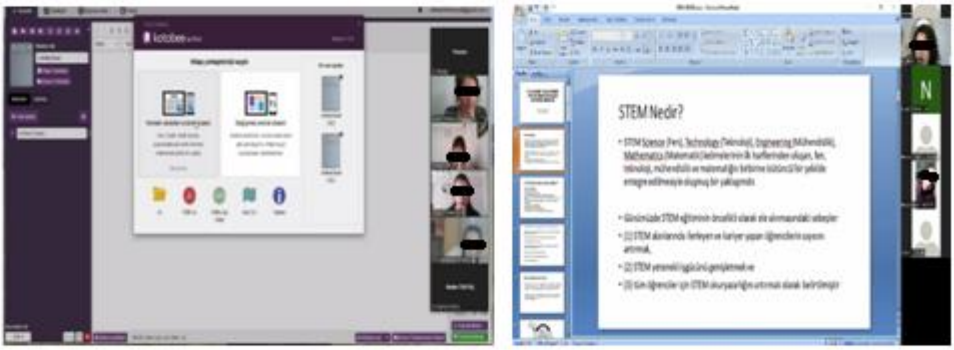

Figure 2. Implementation Process Sample Screenshots.

Before the implementation, the pre-service science teachers were administered the SAS, SES, and MCSS scales as pre-tests. At the end of the project, the same scales were performed again on the participant as post-tests. Also, the survey form was filled by the pre-service teachers at end of the project.

To begin with, the uses of "Interactive Teaching Materials in Learning Environments Prepared according to the STEM Approach" were explained theoretically (1 lesson hour - 60 minutes) by the second author. The Kotobee™ application, which is one of the e-book applications and provides the opportunity to prepare digital interactive teaching materials, was introduced by the first author (3 lesson hours - 3*60=180 minutes). Following, technical and topic-based workshops were held on Kotobee™ and STEM with the participation of both authors (2 lesson hours - 2*60=120 minutes). At the end of the day, activity plans (1 lesson hour - 60 minutes) based on the STEM approach, including the Kotobee™ application, were carried out with the participation of both authors. This whole process was done online. Sample screenshots of the implementation process are presented in **Figure 2** below.

All application process of the research is schematized in **Figure 3**.

Data Analysis

Quantitative data (SAS, SES, and MCSS) were analysed by the SPSS statistics package program (version 22). Since the sample size was below 30 and the data did not show a normal distribution (as a result of the normality test), nonparametric tests were preferred. Wilcoxon Signed Rank tests were used to determine if there were significant differences between pre and post-tests. Also, descriptive analyses were applied for each sub-dimension of the STEM Awareness Scale. The answers given to the scales were interpreted as

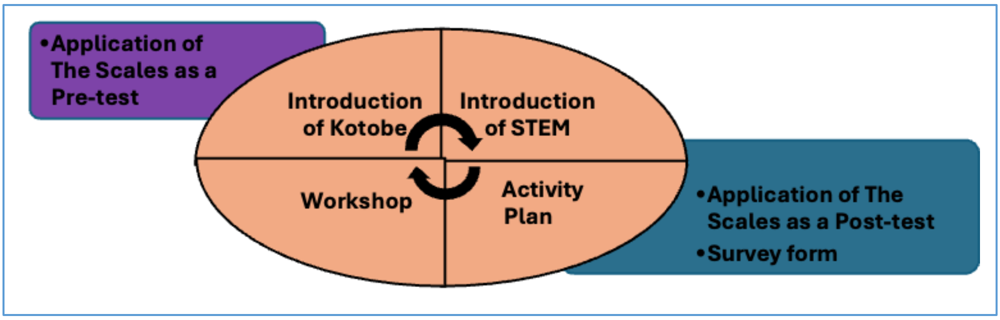

Figure 3. The Process of the Research.

Table 1. Values Used in Interpreting the Arithmetic Mean of the Scale.

Interpretation of Scoring	Range Rating	Interpretation
1.0-1.79	Strongly disagree	Very low
1.80 - 2.59	Disagree	Low
2.60 - 3.39	Neither agree nor disagree	Middle
3.40 - 4.19	Agree	High
4.20 - 5.00	Strongly agree	Very high

all values used are given in **Table 1**. Similar analyses for the relevant scale are also included in different studies (Özdemir & Cappellaro, 2020; Akgün & Türel, 2021).

Qualitative data (survey form) were analysed via content analysis. Two authors thoroughly examined the obtained data and developed codes appropriate for the participant's responses. The two researchers' agreement and disagreement were then determined (Miles & Huberman, 1994). The agreement coefficient (reliability) was calculated as 0.90. The codings were matched based on similarities and differences, and subcategories/categories were identified by grouping them under various titles. The data were submitted to the field expert for finalization in order to ensure the relevance of the categories by the codes. Accordingly, the obtained data were finalized in line with the received feedback.

Validity and Reliability

The validity and reliability of the quantitative scales used in the study were carried out by the developers of the scales. Accordingly, Cronbach alpha values of reliability coefficients were calculated. In the SAS scale development stage, Buyruk and Korkmaz (2016) did the exploratory factor analysis, and as a result, the scale consisted of 17 items. The Cronbach's alpha reliability coefficient of the scale was found to be 0.93 by Buyruk and Korkmaz. For this study reliability coefficient was calculated as 0.89. According to the results of the exploratory factor analysis conducted by Yaman et al. (2018), the SES scale consisted of 18 items. The Cronbach's alpha reliability coefficient of the scale was found to be 0.97. For this study reliability coefficient was calculated as 0.94. Cevik and Senturk (2019) performed the exploratory factor analysis as a part of the validity studies. As a result of the analysis, a 41-item scale was created. The Cronbach's alpha reliability coefficient of the scale was found to be 0.86. For this study reliability coefficient was calculated as 0.81. Usage permissions for all scales were obtained from the scale owners via e-mail.

The survey questions were formed by the researchers. Then they were checked by a science education expert for readability, understandability, and compatibility. After this stage, the final version was ready for the survey. All participants were informed about the recording of the survey data and their consents were taken.

Apart from these, participation in this project was based on the participants' willingness. They wanted to participate in this project willingly and so that they filled an online application form on their own, they were informed about the data collection phases, and the recording of the data. Participants were coded as P1, P2, P3, …, P28.

Findings

In this study, STEM awareness, STEM self-efficacy beliefs, and 21st century skills of pre-service science teachers were tried to be determined. The findings relating to the research problems are offered below for this purpose.

Findings on 1st Research Question

The framework of the first research problem is "Is there a significant difference between the pre and post-test scores of pre-service science teachers on STEM awareness levels, STEM self-efficacy beliefs, and 21st century skills?" **Tables 2** and **3** below present the findings of the first research problem. **Table 1** shows the results of the descriptive analysis calculated on the scores of the pre-service science teachers on the SAS, SES, and MCSS scales.

As seen in **Table 2**, the average scores of all the tests increased in the post test. Table 3 shows the results of the Wilcoxon Signed Ranks analyses calculated on the scores of the pre-service science teachers for the SAS, SES, and MCSS scales.

Table 2. Descriptive analysis of Scales.

Scales	N	Mean	Std. Deviation	Min.	Max.	Mean Ranks
SAS-pre	28	75	14.00	17.00	85.00	14.69
SAS-post	28	77.21	8.20	59.00	85.00	12.31
SES-pre	28	61.46	14.26	31.00	85.00	15.36
SES-post	28	76.28	11.69	47.00	90.00	11.33
MCSS-pre	28	168.64	28.82	76.00	202.00	15.03
MCSS-post	28	183.36	15.93	152.00	205.00	11.56

Table 3. Wilcoxon test results for SAS, SES, and MCSS Scales.

Scales		N	Mean Rank	Sum of Ranks	z	p
SAS	Negative Ranks	13	12.31	160	-394	0.694
	Positive ranks	13	14.69	191		
	Ties	2				
SES	Negative Ranks	6	11.33	68	-3.076	0.002
	Positive ranks	22	15.36	338		
	Ties	0				
MCSS	Negative Ranks	8	11.56	92.50	-2.319	0.020
	Positive ranks	19	15.03	285.50		
	Ties	1				

Table 4. Descriptive analysis of SAS.

	Items	N	Mean	Std. deviation
Pre-test	Positive perspectives	28	4.49	0.14
	Negative perspectives	28	4.23	0.28
Post-test	Positive perspectives	28	4.65	0.08
	Negative perspectives	28	4.31	0.30

As seen in **Table 3**, the result shows STEM awareness levels were not statistically significant in favour of the post-test. On the other hand, scores on the Self-Efficacy Related to STEM Practice Scale and the 21st Century Skills Scale were found to be statistically significant in favour of the post-test. In order to determine the STEM awareness levels of prospective teachers, descriptive analyses were applied for each sub-dimension of the SAS scale. The values obtained as a result of the analysis are shown in Table 4 below.

As seen in **Table 4**, the change in stem awareness levels from a positive and negative perspective according to the pre- and post-test is shown, and it can be said that the awareness level has increased in both aspects.

Findings on 2nd Research Question

The framework of the second research problem is “What are the opinions of pre-service science teachers about 21st century skills?” **Tables 5, 6, 7, 8, 9, 10**, and **11** below present the findings of the second research problem.

As seen in **Table 5**, a significant number of pre-service teachers stated that researching, questioning, and producing solutions on information and technology (12), keeping up with technological developments (10), and using technology effectively (9) as the definition of information and technology literacy. Major of pre-service teachers thought themselves as information and technology literate. Moreover, they stated that they keep up with technological developments (9), use information and communication technologies in daily life (8), use technology correctly and efficiently (6), provide reliability of the information source (6), check information from different sources (6).

For example, P21 explained in this way “Information literacy can be defined as people who access information, analyze it and research it. I think that technology literate refers to people who use technology, benefit from it and can produce solutions to various technological problems. In this respect, I think that I am information and technology literate. I take care to research the information I want to access from the right sources. In this research process, I benefit from technology and I think that I can analyze which sources are reliable.”

As seen in **Table 6**, the definition of critical thinking skill is including analyser/evaluator (16), questioner (15), and filters the mind and logic (9). Major of pre-service teachers thought themselves as having critical thinking skills. They explained critical thinking skills behaviour as evaluating the positive and negative aspects (10), being capable of deduction (7), and respecting/evaluating different opinions (6). For example, P5 explained in this way: “Critical thinking skills are the ability to reason and present ideas in the face of a problem or event. A person with critical thinking skills researches events, situations, and obtains information and offers solutions to problems. I don’t think I have much critical thinking skills. Because I am very emotional, I only stay in the moment of the situation.”

As seen in **Table 7**, when pre-service teachers face with a problem, they try to understand what/cause of the problem (20), develop a solution proposal (17), behave solution-oriented (11), and ask for help (8). For example, P25 explained in this way “First, I research the source of the

Table 5. Codes Related to the 1st Question of The Survey Form.

1. a) What is Information and Technology Literacy?		
Code	**Pre-service science teachers**	**f**
Researching, questioning and producing solutions on information and technology	P7-9, P14, P16, P18-19, P21-25	12
Keeping up with technological developments	P1, P9, P11, P16-17, P20, P23-25, P28	10
Using technology effectively	P5-6, P8, P11, P13-15, P21, P28	9
Ability to explain information	P5, P16, P18, P20-22, P25	7
Information integration into technology	P3, P7, P10, P15, P26, P28,	6
Being receptive to new information	P3, P7, P9, P25, P28	5
Digital Literacy	P12	1
1. b) Do you think you are information and technology literate?		
To be information and technology literate	**Pre-service science teachers**	**f**
Yes	P2, P6-9, P11, P13-14, P18, P21-22, P26, P28	13
Partially	P1, P5, P10, P12, P15-17, P19, P24, P27-28	11
No	P3-4, P25	3
1. c) How do you act in this regard, what do you pay attention to?		
Behavior to be information and technology literate	**Pre-service science teachers**	**f**
Keeping up with technological developments	P4, P9-13, P19-20, P26	9
Using information and communication technologies in daily life	P1, P7-9, P17, P24, P26-27	8
Using technology correctly and efficiently	P5-6, P8, P13, P24, P28	6
Reliability of the information source	P2, P14, P16, P21-22, P28	6
Checking information from different sources	P4-7, P21-22,	6
Learning new and correct information	P3, P16, P20	3
Finding solutions for interests and needs in daily life	P12-13, P26	3

Table 6. Codes Related to the 2nd Question of The Survey Form.

2. a) What does critical thinking skill mean?		
Definition of critical thinking skill	**Pre-service science teachers**	**f**
Analyzer / Evaluator	P7, P9, P11-12, P14-16, P19-22, P24-28	16
Questioner	P1-2, P7-8, P10, P14, P17-18, P20-24, P26, P28	15
Filters the mind and logic	P1, P4-7, P11-12, P18, P28	9
2. b) Do you think you have critical thinking skills?		
Having critical thinking skills	**Pre-service science teachers**	**f**
Yes	P1, P3, P6-7, P9-11, P14-17, P19, P22, P25, P27-28,	16
Partially	P2, P4-5, P8, P12, P18, P20-21, P23-24, P26	11
2. c) How does a person with critical thinking skill behave?		
Critical thinking skills behavior'	**Pre-service science teachers**	**f**
Evaluating the positive and negative aspects	P1, P6, P8, P10, P14-15, P24-27	10
Being capable of deduction	P4,P7,P14,P19,P22,P25,P28	7
Respecting/evaluating different opinions	P4,P7,P15-17,P22	6
Multidimensional thinking	P4,P7,P21,P28	4
Queries	P7,P9,P26	3
Offering a solution	P5,P11,P28	3

Table 7. Codes Related to the 3rd Question of The Survey Form.

3. a) How do you act when faced with a problem? Why?		
Behavior towards to problem	**Pre-service science teachers**	**f**
Understanding what/cause of the problem	P2-5, P7, P10-11, P13, P15-23, P25, P27-28	20
Developing a solution proposal	P2-6, P8-10, P12, P14-15, P18-19, P22, P24, P27-28	17
Solution-oriented	P1, P5-7, P10, P15, P17, P21, P25-26, P28	11
Asking for help	P10, P15-17, P22, P25-27	8

Table 8. Codes Related to the 4th Question of The Survey Form.

4. a) Do you think you are an innovative person?		
To be innovative person	**Pre-service science teachers**	**f**
Yes	P1-7, P9, P11-19, P21, P23-25, P27-28	17
Partially	P8, P10, P20, P22, P26	5
4. b) How do you act when faced with a new situation? Why?		
Behavior against new situation	**Pre-service science teachers**	**f**
Adapt	P5-7, P11, P14-16, P18-19, P28	10
Difficulty adapting to the process	P3, P8, P13, P17	4
Observation	P4, P7, P26	3
Data collection	P4, P25, P27	3
Learning and practice	P23, P25	2

Table 9. Codes Related to the 5th Question of The Survey Form.

5. a) Do you consider yourself an entrepreneurial person?		
To be an entrepreneurial person	**Pre-service science teachers**	**f**
Partially	P1, P3-5, P7, P10-12, P16-19, P21-22, P27	15
Yes	P2, P6, P9, P14, P20, P25, P28,	7
No	P8, P13, P15, P23-24, P26	6
5. b) How does an entrepreneur behave?		
Entrepreneurial person behavior’	**Pre-service science teachers**	**f**
Being able to generate new ideas	P7, P12-16, P26, P28	8
Being open to innovation	P7, P9, P13, P15-16, P26, P28	7
Being Sociable	P7-8, P12, P16, P19, P28	6
Risk Taker	P8, P16, P18, P21, P25-26	6
Being Self-confident	P4, P8, P11, P25, P27, P28	6
Brave	P1, P8, P11, P15, P25	5
Willing, curious and determined	P1, P2, P20, P22, P25	5
Forward thinking	P4, P9, P20, P27, P28	5
Motivational	P4, P9, P16, P28	4
Strong communication orientation	P8, P16, P24, P28	4
Planned and Scheduled	P14, P16, P21, P28	4
Capable of Evaluating Opportunities	P8, P10, P20	3
Able to Implement Ideas	P11, P14, P23	3
Able to Manage the Process	P19-20, P28	3
Able to Use Time effectively	P20, P28	2

Table 10. Codes Related to the 6th Question of The Survey Form.

6. a) Do you think you have social responsibility?		
To be a social responsibility	**Pre-service science teachers**	**f**
Yes	P1-2, P4-10, P12, P25-28,	14
Partially	P3, P11, P14-19, P21-24, P28	13
No	P20	1
6. b) What does it mean to be socially responsible?		
Definition of social responsibility	**Pre-service science teachers**	**f**
Consciousness of social responsibility	P4-5, P7, P9-10, P12, P14-18, P20, P23, P25-28	17
Being environmentally conscious	P4, P8, P10-11, P21, P25, P27	7
Ability to perform tasks optimally	P6, P9, P19, P22, P24, P28	6
Know your responsibilities	P1-2, P4, P28	4
not bothering anyone	P18, P28	2
Being planned and programmed	P2	1
Ability to offer solutions	P3	1
Being interested in activities and events in social life	P14	1
Ensuring that everyone has equal opportunity	P18	1
Good relationship	P21	1

Table 11. Codes Related to the 7th Question of The Survey Form.

7. a) How does a person with leadership skills behave?		
Definition a person with leadership skills	**Pre-service science teachers**	**f**
Able to manage the process	P2, P4, P7, P10, P13-15, P17, P20, P26-28	12
Able to manage people	P5-6, P17-19, P24, P26-28	9
Capable of leading	P2-3,P8, P11, P18, P28	6
Communication skill	P7,P9, P21, P23, P25, P28	6
Solution oriented	P1, P8, P16, P18, P22	5
Fair	P4, P19, P21, P26, P28	5
Does not hesitate to take responsibility	P1, P10, P20, P25	4
Able to Approach Different Thoughts With Understanding	P3, P8, P21, P28	4
Sample person	P5, P25, P28	3
Reassuring	P4, P12, P21	3
Get your cooperation	P5, P7, P28	3
Can assign	P5, P7, P28	3
Having a different perspective	P20, P23,P28	3
Able to generate creative ideas	P4, P21	2
7. b) Do you think you have this skill?		
To be a person with leadership skills	**Pre-service science teachers**	**f**
Partially	P3-4, P8-9, P11-19, P21, P24, P26, P28	17
Yes	P1-2, P5-7, P10, P20, P25, P27-28	10
No	P22-23, P28	3

problem. Then, I think about what can be done to solve it. I get ideas from those around me. I try to proceed within the framework of logic. I try to make my decisions impartially and in the most accurate way."

As seen in **Table 8**, all pre-service teachers see themselves as innovative. They stated that when they face with a new situation they try to adapt (10), have difficulty adapting to the process (4), observe (3), collect data (3), and learn and practice (2). For example, P19 explained in this way "I am a person who is open to innovations in every subject. I like differences. I try to understand, adopt and adapt to the situation."

As seen in **Table 9**, the majority of pre-service teachers see themselves as entrepreneurial. A significant number of pre-service teachers stated that the entrepreneurial person generates new ideas (8), is open to innovation (7), is sociable (6), is a risk-taker (6), and is self-confident (6). For example, P16 explained in this way: "When an entrepreneurial person comes to mind with an idea or encounters a problem, he/she does everything within the framework of logic to bring that idea to life. He/she is enterprising, has high morale and a lot of interest. He/she is innovative. He/she takes risks where necessary. If he/she makes a plan and a program when starting a business, he/she will progress in this business. He/she discovers and produces new things. He/she likes to establish dialogue with people. I think I am at least partially entrepreneurial."

As seen in **Table 10**, almost all pre-service teachers thought that they had social responsibility. A significant number of pre-service teachers stated that the definition of social responsibility includes consciousness of social responsibility (17), being environmentally conscious (7), and the ability to perform tasks optimally (6). For example, P10 explained this question in this way: "Being socially responsible means being sensitive to society. It is usually used for studies related to the environment. Because the environment is a structure that concerns society, not the individual, I think I have social responsibility because I separate my garbage according to recycling. Although this may seem like a small thing to most of us, if we had this awareness as a society, our batteries would not pollute our lands, our seas would be cleaner and our ecosystem would be more effective."

As seen in **Table 11**, the majority of pre-service teachers thought that they had leadership skills. A significant number of them stated that the definition of a person with leadership skills consists of managing the process (12), managing people (9), being capable of leading (6), and having communication skills (6). For example, P4 explained this question in this way: "They can put forward creative ideas, they need to be able to solve the obstacles that come their way in line with their goals with the least damage, they exhibit professional behaviors in terms of trustworthy, fair, positive process and time management. I think that I have some skills exist and some do not because some are truly born leaders."

Discussion

According to the study, it was determined that there was no statistically significant difference in pre-service science teachers' STEM awareness levels before and after the application. This result can be explained by the fact that pre-service teachers view STEM positively and are aware of the STEM approach. Furthermore, it can be associated with the fact that the pre-service teachers are in the 3rd and 4th grades, inferring that STEM awareness rises with grade level (Sondergeld et al., 2016; Ergün, 2019). Although there is no statistically significant difference after the STEM application, there is an increase in favor of the post-test among the minimum rankings. This rise can be interpreted mathematically as the application's positive contribution to pre-service teachers' STEM awareness.

As a matter of fact, when we look at the studies on STEM awareness, it is seen that they have positive perspectives toward STEM. For example, in the study conducted by Ergün (2019), the relationship between the STEM awareness levels of pre-service science teachers and their entrepreneurial aspects was examined and it was stated that pre-service teachers had a positive awareness of STEM. The fact that pre-service science teachers' awareness of STEM education is generally positive is also considered important in terms of the implementation of STEM education.

According to the study, pre-service science teachers' participation in this project showed that it helped to increase their STEM self-efficacy beliefs. The reason it is thought to be effective is due to the inclusion of STEM-related workshops and activity plans in practice. Namely, in the workshops, the Kotobee™ application was experienced in detail by the pre-service teachers, and digital interactive teaching materials were tried to be prepared by using the Kotobee™ application in accordance with the STEM approach. Afterwards, activity plans were developed for the use of the digital interaction teaching material in the learning environment based on the STEM approach. This whole process supports the self-efficacy of pre-service teachers. Pre-service teachers integrated the digital interactive teaching materials they developed into the activity plan based on the STEM approach. Thus, they felt more confident about STEM applications as a result of having a say. The effective implementation of STEM education in the classroom is closely related to the teachers' knowledge and beliefs, and it is important to create a positive change in their self-efficacy toward STEM practices (Ring et al., 2017). Therefore, both pre-service and in-service teacher professional development is required for STEM practices (Darling-Hammond & Bransford, 2005). At this point, a positive contribution was made to the STEM practices of pre-service teachers, who are the teachers of the future. The lack of experience of teachers in STEM education or the difficulties experienced during the experience can be shown as the reason for the low perception of self-efficacy. Wang (2012) stated in his study that physical facilities and external factors that will support the teacher, such as technology, application area, and material, are also challenging when science teachers are applying STEM education.

In this study, it is an inevitable result that the self-efficacy of pre-service teachers who develop digital interactive teaching material and integrate this interactive material into the learning environment is based on the STEM approach. Studies have shown a positive association between self-efficacy and teacher effectiveness (Sehgal et al., 2017). Considering that there is a positive relationship between teaching self-efficacy and teaching experience (DeChenne et al., 2012), the increase in pre-service teachers' self-efficacy beliefs towards STEM practices can also contribute positively to their teaching experience. According to Hoy and Spero (2005), the high self-efficacy of pre-service teachers who do not have teaching experience and do not experience the real classroom environment is due to the fact that they see teaching in the aforementioned subjects as something they can already do. It is thought that this situation may also be valid for the self-efficacy of STEM practices revealed by the participants of this study.

The research shows that the 21st century skills of pre-service science teachers are positively affected. This result may be related to pre-service teachers' awareness of the STEM approach. Because the STEM approach, is aimed at developing 21st century skills in learners, the STEM activity encourages students to think more scientifically (NRC, 2010; Dönmez Usta & Ültay, 2022). Learning with technology allows teachers and students to be more creative and productive in their learning (Hasibuan et al., 2022). Having 21st century skills is also directly related to the education 21st century learners receive (Dönmez Usta, 2021). Information technologies support students in the process of acquiring knowledge and restructuring it according to their needs (Hopson et al., 2001). In this context, it is thought that enriching the learning environments of 21st century learners who grew up with technology will contribute to their skills and learning. Therefore, the technology-enriched learning environments included in this study can be said to positively affect 21st century skills. Furthermore, it can be associated with the fact that the pre-service science teachers are in the 3rd and 4th grades; as the grade levels increase, their 21st century skills and their tendency to use technology increase. These findings are similar to those of studies in the literature (Ješkov & Luk, 2022; Oztürk, 2023). Besides, STEM has positive results in developing students' thinking skills and is able to improve students' 21st century skills in science learning (Castro & Jimenez, 2022). Considering that developing 21st century skills is one of the main goals of STEM education (NRC, 2012), it can be said that pre-service teachers have this awareness.

Considering that the integration of information technologies into the learning-teaching process is directly related to 21st century skills such as information, media, and technology skills (Henderson et al., 2010); it is positive that most of the pre-service teachers define information and communication literacy as researching, questioning, and producing solutions on information and technology. Namely, technological innovations can be said to provide valuable educational tools for 21st century education (Yu & Durrington, 2006), and the effective use of technology by following technological developments contributes positively to the definition of information and technology literate in this research. Besides, the fact that the majority of pre-service science teachers think that they are technology literate (all of the answers were “yes” or “partially”) supports this finding. Given that information and technology literacy is defined as an individual’s ability to access, configure, and apply information by appropriately using various technological hardware and software in any situation (Trilling & Fadel, 2009); it is encouraging that the majority of pre-service teachers think this behavior to be literacy as researching, questioning, and producing solutions on information and technology while keeping up with technological developments using technology effectively. From this perspective, it is possible to conclude that the introduction and usage of the KotobeTM program, which enables the construction of digital interactive e-books, contribute to information and communication technology literacy, one of the 21st century skills. In this context, the fact that pre-service teachers recognize and use this and similar digital applications also contributes to the development of such skills. Within this context, it is possible to say that the use of relevant digital applications by pre-service teachers in both face-to-face and online learning environments will contribute to information and communication technology literacy.

As a result of the findings obtained from this study, pre-service teachers defined critical thinking as “analyzer, evaluator, and questioner”. Critical thinking is a way of thinking that aims to analyze, evaluate, interpret, and make sense of things and is based on making decisions with free will (Facione, 1990). The definitions of this talent by pre-service instructors in this content correspond to the notion of critical thinking. Brahler et al. (2002) stated that critical thinking skills are related to the learning environment, the social context of learning, and the teaching style of the teacher. For this reason, it can be said that teachers should develop students’ critical thinking skills by using teaching strategies that encourage students to think critically. Thanks to its interdisciplinary approach, STEM education can be considered an educational approach that includes high-quality learning, using knowledge to solve problems encountered in daily life, and high-level and critical thinking (Bybee, 2010). In this study, it can be stated that conducting workshops and developing activity plans for the use of digital interactive teaching materials, namely e-books, which they developed in the learning environment based on the STEM approach contributed to critical thinking skills. It is believed that the positive contribution of pre-service science teachers’ critical thinking skills, who are the teachers of the future, will also be successful in helping their pupils obtain these skills in the future. As a result, this study also contributed to the pre-service teachers gaining experience in the subject of critical thinking.

Considering that STEM education is an interdisciplinary educational approach (Cooper & Haverlo, 2013) that seeks solutions to real-life problems and enables the transformation of theoretical knowledge into practice and product; it is positive that most of the pre-service teachers defined a problem as “understanding what/cause of the problem, developing a solution proposal, solution-oriented and asking for help”. STEM education also provides the development of high-level thinking skills such as complex problem-solving, establishing cause-and-effect relationships, inferring, and critical and creative thinking (Murphy et al., 2019). In this context, it is thought that the STEM education in this study contributed positively to the problem-solving skills of pre-service teachers.

Learning activities that students carry out through projects and play an encouraging part in the learning process should be included in training aimed at enhancing students’ entrepreneurship skills (Ruskovaara & Pihkala, 2015). In this regard, technology will pique students’ attention and inspire them to create new projects; therefore, it is critical to present well-supported innovations (Lepuschitz et al., 2018). This study, in which technology-supported innovations are given, can be stated to have made a good contribution to the description of an entrepreneurial person as being able to produce new ideas, being open to innovation, and being sociable. It is believed that pre-service teachers’ engagement in this project adds to their appraisal as entrepreneurs as well.

The majority of pre-service teachers believe they have social responsibility. Besides, they feel that acting with the consciousness of social responsibility necessitates this awareness. Similarly, most of the pre-service teachers think that they have leadership skills, albeit partially. They believe that a person with leadership skills should also be able to manage the process. As a result of the project, these thoughts of the pre-service teachers were expressed in the 21st century. This can be explained by the fact that there is a statistically significant difference in favor of the post-test in their scores for their skills. In this case, both the development of digital interactive teaching materials throughout the study and the integration of these developed digital teaching materials into the learning environment for STEM education had positive results.

Conclusion

The following results were found at the end of this implementation:

- This project was found to have contributed positively to STEM self-efficacy and 21st century abilities, and it continued to contribute positively to STEM awareness, but not statistically.

- It was also determined that pre-service teachers have an adequate understanding of 21st century abilities such as information and technology literature, critical thinking, innovative, and entrepreneurial thinking, etc. In addition, pre-service teachers generally see themselves as having 21st century skills, albeit partially.
- According to this study, it is determined to result that increasing the self-efficacy of pre-service teachers who develop digital interactive teaching material and integrate this interactive material into the learning environment based on the STEM approach. Because pre-service teachers have gained experience on this subject.

The experiences pre-service teachers gained with the opportunity to develop digital interactive teaching material and integrate this interactive material into the learning environment based on the STEM approach make this study even more important. Based on these results, the following recommendations are presented.

- In addition to pre-service science teachers who will be the teachers of the new world order, opportunities for such activities must be provided for pre-service teachers in different branches. It can also be suggested that such activities must be designed and organized not only for pre-service teachers but also for 21st century learners such as teacher, all faculty members working at the university and all students, etc.
- The fact that all participants in this study were female was entirely by chance and is a limitation of this study. In addition, since gender was not selected as a variable in this study, it is not considered to be a situation that affects the results of the study.
- The study is limited to data collection tools and can be carried out in studies where different variables are measured.
- The study is limited to Kotobee™ application and STEM education. It is recommended to conduct studies using different digital applications and learning approaches.

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