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Investigating Girl and Boy High School Students' Epistemological Beliefs in Biology and Physics

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Abstract

Epistemological beliefs are associated with students' motivation, learning strategies, career choices, and academic achievement. The study aimed at examining the epistemological beliefs of high school students in physics and biology. A total of 503 high school students studying at five schools in the Aegean Region in Turkiye participated in the study. The 5-point Likert-type Epistemological Beliefs Scale and the previous semester's grade were used as data sources in physics and biology. Repeated ANOVAs were used to address the research questions. ANOVA results showed that the students had higher scores than the biology course against the physics course in the sub-dimension of the source of knowledge, the certainty of knowledge and the justification of knowledge. The results of this study are important in terms of teaching physics and biology lessons and reveal that students' ideas about scientific knowledge for different course branches are different, and this difference exists in the early years of high school.

INTRODUCTION

Epistemological beliefs refer to an individual's ideas about knowing and knowledge (Hofer & Pintrich, 1997). Research on epistemological beliefs has suggested that students' ideas about knowledge and knowing are domain-specific (Muis et al., 2006). Studies concerning the domain-specificity of epistemological beliefs were mostly interested in students' ideas in hard versus soft science domains (e.g., mathematics vs history; Buehl, & Alexander, 2006). Few studies have examined the discipline-specificity of epistemological beliefs and reported that students' epistemological beliefs might differ across scientific disciplines (e.g., biology vs physics; Topcu, 2013). However, studies addressing the discipline-specificity of epistemological beliefs focused on university-level students (e.g., Topcu, 2013), or a few dimensions of epistemological beliefs (e.g., Tsai, 2006). Therefore, a need emerges to determine the discipline- specificity of epistemological beliefs in high school students, who just started taking such specialized science courses like physics and biology (Muis et al., 2006). In addition, research reported that students' epistemological beliefs influence their motivation, career choice, learning strategies, achievement and interest (e.g., Lee et al., 2021; Trautwein & Lüdtke, 2007). Therefore, it is helpful to examine girls' epistemological beliefs in physics and biology, and that different dimensions of epistemological beliefs contribute to their achievement in physics and biology.

Theoretical Framework

Perry (1970) conducted the first studies on epistemological beliefs in university students. Perry (1970) sought answers to the questions of how university students know, what their ideas about knowing are, and what role thinking and logical inferences play in knowing. Since Perry’s (1970) work, many different theoretical models have been hypothesized. These theories can be categorized into three groups as developmental views (e.g., King & Kitchener, 1994; Perry, 1970), multi-dimensional views (e.g., Hofer & Pintrich, 1997) and epistemic resource views (Hammer & Elby, 2002). The developmental views define epistemological beliefs as a developmental cognitive element and argue that a person’s epistemological view is more likely to develop from a naive level to a sophisticated level with education and age. Models that describe epistemological beliefs in multiple dimensions have emerged because developmental models that examine epistemological beliefs in one dimension would not be sufficient to examine the complex nature of epistemological beliefs. The epistemic resource view argues that since knowledge is a socio-contextual product, an individual's ideas about knowledge may change according to the social context, and therefore, research on epistemological beliefs should investigate the individual's contextual variables.

One of the important theories on epistemological beliefs was theorized by Hofer and Pintrich (1997). They describe epistemological beliefs in four identifiable dimensions, which are based on the nature of knowledge or the nature of knowing. The two dimensions are about the nature of knowledge as the certainty of knowledge and the development of knowledge. The certainty of knowledge deals with the perceived stability and the strength of supporting evidence whereas the development of knowledge is about the relative connectedness of knowledge. The other two dimensions deal with the process of knowing as the justification of knowledge and the source of knowledge. The justification of knowledge describes how individuals proceed to evaluate and warrant knowledge claims while the source of knowledge is either that knowledge exists in an external source or is constructed by learners. Hofer and Pintich (1997) claimed that epistemological beliefs are influenced by the nature of the domain and students’ learning experiences in that domain.

Studies have shown that epistemological beliefs play a direct and important role in learning. It was found that epistemological beliefs were associated with motivation, self-regulation and academic achievement (Alpaslan, 2019; Ata & Alpaslan, 2019; Wang et al., 2022). For instance, Wu and Tsai (2011) sought deeper insight into learners’ informal reasoning on a socio-scientific issue (SSI) and explored the relationship between students’ epistemological beliefs (cognitive structures as well) and informal reasoning. Participants were 68 (22 female) 10th grade students. Both questionnaire-based and tape-recorded interview data were used. Self-reported questionnaire (26 items in 4 scales) developed by Conley et al. (2004) was used to determine students’ epistemological beliefs. Students, in general, showed relatively sophisticated epistemological beliefs and scored highest on the simplicity of knowledge scale. The correlation between epistemic beliefs and informal reasoning was 0.27 on developmental and 0.33 on justification scales ($p< .05$). The result revealed that students’ views on knowledge and knowing tended to influence their scientific reasoning.

In a recent meta-analytic study, Greene et al. (2018) reviewed the relations of epistemological beliefs with academic achievement. From 132 non-experimental studies, they found that epistemological beliefs are statistically related to academic achievement. The effect size was small but positive ($r=.16$, $p< .05$), indicating that the more sophisticated view will yield a higher achievement score. In another study, Guo et al. (2022) investigated the relations of epistemological beliefs with motivation, achievement and aspiration in science from PISA 2015 data. They investigated the relationship data of 514.119 students from 72 countries and found that beliefs on the justification of knowledge and certainty of knowledge were positively related to self-efficacy, intrinsic value and utility value. Evidence from these studies underscores that students' epistemological beliefs play important direct or indirect roles in their learning.

Epistemological beliefs and Their Discipline Specificity

Recently, many researchers have claimed that students' epistemological beliefs may be different across disciplines (Muis et al., 2006). For example, Hofer (2000) found that students viewed knowledge in science to be more certain than knowledge in psychology. In science education, few studies examined students' epistemological beliefs in different disciplines of science. Tsai (2006), for example, examined students' ideas about the certainty of knowledge in biology and physics with 428 high school students. Tsai (2006) reported that the students considered biological knowledge more tentative than physical knowledge. Tsai concluded that exposure to specific knowledge might lead students to develop different epistemological beliefs.

In another study, Topcu (2013) examined Turkish pre-service teachers' epistemological beliefs in chemistry, biology and physics disciplines. Topcu (2013) reported that students had different epistemological beliefs across all disciplines, stating that students viewed knowledge in biology and chemistry as more tentative in physics. The students tended to view physics as authority-dependent while biology was more dependent on personal evaluation. Topcu (2013) suggested there was a need for studies with different contexts and younger students.

Gender in Physics and Biology

Issues with female participation in science education have been well-documented over many years and are still persistent and pervasive today (Hite, 2021). Although the number of female students in higher education has been increasing, such a change does not apply to all academic fields (Yazilitas et al., 2013). Research reported that girls would favor biology and geography while boys would favor hard science subjects such as physics and chemistry (e.g., Warrington & Younger, 2000). In Turkiye, the situation is not different. According to the Council of Turkish Higher Education (CTHE, 2015) report, more girls than boys enrolled in biology major in the 2014-2015 academic year in Turkish universities (2702 out of 4072). In addition, according to the same report, as a major of study, more girls chose biology than those who chose physics (2702 vs 365). Tsai (2006) examined gender differences in biology and physics in terms of tentativeness of knowledge. Tsai (2006) that reported girls and boys viewed biological knowledge as more tentative than physical knowledge. Thus, it is important to examine gender-related differences in physics and biology to promote female students' physical-related careers.

When students enter high school, they are more likely to be exposed to a division change in specific academic disciplines; like science as physics, and biology. Students at the high school level then start developing more specific beliefs across disciplines; ideas about physical knowledge versus biological knowledge (Muis et al., 2006). The purpose of this study was to determine if epistemological beliefs differ in physics and biology for girls and boys. For this purpose, the following research questions were sought to address:

1. Do students' epistemological beliefs differ in physics and biology?
2. Do male and female students differ in their epistemological beliefs in physics and biology?
3. Do epistemological beliefs predict male and female students' achievement in physics and biology?

METHOD

Research Design

A correlational research model was utilized to address research questions. Correlational studies are used to examine the relations amongst two or more variables and to test the cause-effect relationships between them (Fraenkel & Wallen, 2006). Because the correlational research model requires quantitative data, self-report questionnaires were used to collect data for the study.

Data Collection and Sample

In this study, convenience sampling was used (Creswell, 2007). Because of convenience to the researcher, five public high schools located in a city in Southwestern Turkiye were chosen. A total of 503 (246 girls and 257 boys) 9th and 10th grade students had their parental forms signed and volunteered to participate in the study. The students in the schools were moderate achievers and socio-economically diverse. Data were collected in March 2019 and in regular class hours of students under the supervision of their teacher in one class hour.

Instrument

Epistemic Beliefs Questionnaire

In this study, the Epistemic Beliefs Questionnaire (EBQ; Conley et al., 2004) was employed to map students' epistemological beliefs in physics and biology. The EBQ can be adaptable to physics and biology and has been validated in Turkiye. EBQ, a self-report instrument in a 5-point Likert, comprises 26 items to measure the students' views about scientific knowledge in the four dimensions defined by Hofer and Pintrich (1997). The Turkish version of the questionnaire was used in some recent studies in Turkiye (Alpaslan et al., 2016). Since the purpose of the study was to identify students' epistemological beliefs in physics and biology, the words "science" and "scientists" with 'physics" and "physicists" in the physics booklet and "biology" and "biologists" in the biology booklet were replaced. The EBQ comprised four dimensions including source of knowledge (5 items), certainty of knowledge (6 items), development of knowledge (6 items) and justification of knowledge (9 items). The items in the certainty of knowledge and the source of knowledge dimensions were reversed so that higher scores represented more sophisticated beliefs. As the EBQ was previously validated in Turkiye, a Confirmatory Factor Analysis (CFA) was run to verify its dimensionalities for physics (EBQ-P) and biology (EBQ-B) with AMOS 18. According to Hu and Bentler's (1999) criteria (moderate fit for CFI>.95 or RMSEA<.06, and good fit for CFI>.90 and RMSEA<.08), the results of CFA for EBQ-P were in a good model fit, χ^2 (293, N=503) = 897.28, p<.001, SRMR =.050, RMSEA =.056, CFI =.94. The results of CFA for EBQ-B were in a moderate model fit, χ^2 (293, N=503) = 939.45, p<.001, SRMR =.062, RMSEA =.067, CFI =.90. As for the reliability of the instrument, Cronbach's Alpha ranged from .69 to .81 for EBQ-F and from .71 to .82 for EBQ-B.

Achievement in Physics and Biology

In this study, it was decided to take students' physics and biology grades in the previous semester that the study took place as their achievement scores as achievement tests would take extra time of participants. The students' final grades ranged from 1 (failed) to 100 (excellent). Students were asked to write down their physics and biology grades in the previous semester. Although it raised a concern that students might exaggerate their scores, some studies showed that self-reported GPAs are highly correlated with actual GPAs (Crede & Kuncel, 2013).

Data Analysis

To address the research questions, a one-way repeated-measures analysis of variance (ANOVA) was used to identify possible discipline and gender differences in each of the two disciplines. In addition, multiple regressions were used to examine whether epistemological beliefs predicted students' achievement in physics and biology, and the degree to which each dimension of epistemological beliefs contributed to male and female students' achievement in physics and biology. Analyses were computed with SPSS 21.

RESULTS

Means and standard deviations were provided in Table 1. The highest mean value in physics and biology was in justification of knowledge whereas the lowest one was in certainty of knowledge. These results showed that students were more likely to believe that knowing physics and biology requires experimenting and evidence. Additionally, they were less likely viewed that knowledge in physics and biology would change. Girls had higher course grades in both physics and biology than did boys. The mean scores for physics and biology were all above the mid-point of the 5-point Likert-type scales (means were above the mid-point). One-way repeated ANOVA results revealed a statistically significant effect for science disciplines. Students reported more sophisticated beliefs on the source of knowledge (F (1, 502) = 29.610, p<.00005), the certainty of knowledge (F (1, 502) = 4.174, p=.041), and justification of knowledge (F (1, 502) = 19.729, p<.00005) in biology than physics. Within the disciplines, boys reported higher levels of sophistication in justification of knowledge in physics than did girls (F (1, 502) = 6.305, p=.012).

Table 1. Means and standard deviations for variables in the study by disciplines and gender

		All students		**Girls (n_1=246)**		**Boys(n_2=257)**	
		M	***SD***	***M***	***SD***	***M***	***SD***
Physics							
	Source	3.54	.79	3.48	.85	3.59	.72
	Certainty	3.12	.66	3.08	.62	3.17	.66
	Justification	3.86	.71	3.93	.65	3.78	.76
	Development	3.57	.62	3.56	.65	3.57	.59
	Grade	61.6	14.1	62.6	13.0	60.6	15.2
Biology							
	Source	3.32	.77	3.35	.79	3.28	.74
	Certainty	3.05	.69	3.04	.73	3.05	.64
	Justification	3.70	.76	3.72	.74	3.67	.79
	Development	3.53	.65	3.58	.67	3.49	.62
	Grade-B	64.9	13.9	68.4	12.3	61.2	14.6

Note. Means for all variables reflect the five-point Likert scale except Grade was in a 100-point scale.

Between the disciplines, one-way repeated ANOVA results revealed a statistically significant difference for girls and boys. Girls reported more sophisticated beliefs on the source of knowledge (F (1, 245) = 32.819, p<.01), the certainty of knowledge (F (1, 245) = 5.800, p=.017), and justification of knowledge (F (1, 245 = 18.170, p<.01) in biology than physics. Unlike girls, boys reported more sophisticated beliefs on the source of knowledge (F (1, 256) = 4.383, p=.037) and justification of knowledge (F (1, 256) = 4.241, p=.04) in biology than in physics.

Standardized regression coefficients for the prediction of science grades were provided in Table 2. Multiple regression results revealed that epistemological beliefs statistically significantly predicted course grade for physics (F (4, 498) = 9,572, p < .0005, R^2 = .06) and biology (F (4, 498) = 7,437, p < .0001, R^2 = .05). In physics, justification of knowledge (β=0.17) and development of knowledge (β=0.15) statistically significantly predicted physics grade. In biology, the source of knowledge (β=0.10), justification of knowledge (β=0.14) and development of knowledge (β=0.12) statistically significantly predicted biology grade.

For girls, multiple regression results revealed that epistemological beliefs statistically significantly predicted course grades for physics (F (4, 242) = 10,022, $p < .0005$, $R^2 = .11$) and biology (F (4, 242) = 9,569, $p < .0001$, $R^2 = .11$). For girls, in physics and biology, justification of knowledge (β=0.18 and β=0.28) and development of knowledge (β=0.20 and β=0.11) statistically significantly predicted physics and biology grades, respectively: yet, the others were not. For boys, multiple regression results revealed that epistemological beliefs statistically significantly predicted course grade for physics (F (4, 253) = 2,879, $p = .024$, $R^2 = .05$) and biology (F (4, 253) = 2,585, $p = .04$, $R^2 = .04$). For boys, in physics, only the source of knowledge (β=0.17) statistically significantly predicted physics grade, and in biology only development of knowledge (β=0.13) statistically significantly predicted biology grade.

Table 2. Standardized regression coefficients in the study by disciplines and gender

		All students		**Girls (n_1=246)**		**Boys(n_2=257)**	
		β	***t***	***β***	***t***	***β***	***t***
Physics							
	Source	.01	.07	.06	1.48	.17*	5.02
	Certainty	.05	1.29	.05	1.35	.06	1.38
	Justification	.17*	4.98	.18**	5.14	.04	1.10
	Development	.15*	3.77	.20**	6.48	.09	1.84
	R^2	.06**		.11**		.05**	
Biology							
	Source	.10*	2.03	.01	0.17	.04	1.11
	Certainty	.03	0.63	.08	1.77	.07	1.72
	Justification	.14**	3.45	.28**	4.02	.06	1.47
	Development	.12*	2.21	.11*	2.16	.13*	2.44
	R^2	.05**		.11**		.04*	

Note: *p <.05 and ** p <.01

DISCUSSION

The purpose of the study was to examine disciplinary and gender-related differences in high school students' epistemological beliefs in physics and biology. Self-report questionnaires were used to map ninth and tenth grade students' epistemological beliefs in physics and biology. Once the validity and reliability of the instrument were checked, more than one statistical technique were used to address the aforementioned research questions.

Descriptive results showed that students were at a moderate level of epistemological beliefs in physics and biology. Their mean score was higher in justification of knowledge in both disciplines, indicating that they were more likely to view experiments as a way to test ideas in physics and biology. This result is not surprising because previous studies have reported that aged 16 students tend to believe the experimented results more believable than theoretical results and the experimentation as a more convincing way to test ideas (Alpaslan et al., 2017; Driver et al., 1996). However, the mean scores implied that they were less likely to believe that scientific knowledge would not be changed in physics and biology. The reason for this might be that the scientific knowledge in ninth and tenth grade curricula covers more beginner level topics in biology and physics. These topics are more consistent with what students might observe or experience in daily life, which leads students to believe that they would be less likely to be changed. In addition, in middle school students took biology and physics courses under the same course as "science". For this reason, the dimensional variation in students' epistemological beliefs in middle schools would be the same across disciplines.

The previous studies reported that students might hold different epistemological beliefs across different disciplines (Muis et al., 2006; Topcu, 2013; Tsai, 2006). Consistent with the previous studies, this study provided evidence that students' epistemological beliefs varied between disciplines. More specifically, students reported viewing physical knowledge as more certain, authority-dependent rather than the learner, and less coming from reasoning and experimenting than biological knowledge. A plausible explanation for this can be the fact that the traditional physics instruction at schools relies on mostly teaching how to use formulas in physics problems (Meltzer, 2002). This sort of instruction would lead students to view that knowledge in physics requires mastering how to use formulas in physics problems (Redish & Steinberg, 1999). This view might have led the students to view physical knowledge as more certain and coming from authority.

The mean scores of both girls and boys were consistent with the descriptive results for all students. Both girls and boys had the highest mean scores in justification of knowledge while the lowest mean scores in the certainty of knowledge. This implies that gender did not affect the variation amongst the dimensions of epistemological beliefs. However, a comparison of girls' epistemological beliefs in biology and physics showed that they had more sophisticated beliefs on the source of knowledge, certainty of knowledge, and justification of knowledge in biology than in physics. These results indicated that girls believed that biological knowledge more likely came from the individual itself not from authority than physics knowledge. They also viewed biological knowledge more tentative than physics knowledge. Lastly, they viewed experimentation would be more important to test ideas in biology than physics. Similarly, boys viewed biological knowledge that came from the individual itself and experimentation as a way to test ideas more than they did in physics knowledge. These results were consistent with the previous findings and studies reported that girls and boys viewed biological knowledge more tentative, experiment-based reasoning, and internally constructed (Tsai, 2006).

Conclusion

Results of the study suggest that epistemological beliefs are multidimensional constructs that may vary across disciplines and gender. Furthermore, regardless of discipline and genders, a more sophisticated view is the predictor of a better academic achievement. This study extended the findings of previous studies regarding gender differences in science education that girls favored and often had better attitudes toward biological sciences than physical science. Regression results demonstrated that epistemological beliefs predicted students' academic achievement in physics and biology. For all students, justification of knowledge and development of knowledge significantly contributed to physics achievement. In biology, in addition to these two dimensions, the source of knowledge was a significant predictor of academic achievement. Justification of knowledge is related to the view that experimentation would be required to test ideas in science. Viewing experimentation as a way of knowing scientific knowledge might lead students to make meaningful learning and therefore, their performance in exams would be better. Similarly, the development of knowledge predicted students' academic achievement in both physics and biology. Development of knowledge refers to the connectedness of knowledge, which the more sophisticated view means knowledge as a system of related constructs, like meaning learning requires the connectedness of knowledge. Therefore, it is not surprising that higher achievers were those who view physics and biology knowledge are products of the related systems.

Recommendations

Science educators need to find ways to foster students more sophisticated views on the tentative and experiment-based reasoning nature of physical knowledge. Sin (2014) argues that traditional physics teaching strategies focus on the acquisition of certain knowledge and discuss how knowledge is constructed in physics. Therefore, it is important to integrate epistemological views with science content to foster epistemological understanding, (Kittleson, 2011). Fostering epistemological understanding can be done by giving argumentation or problem-based learning more space in educational practices. Thus, biology and physics teachers in Turkiye should be trained and encouraged to use innovative and student-centered instruction including argumentation in their classrooms.

Limitations

This study has some limitations. First, the ninth and tenth grade students were excluded were the study because in Turkiye after tenth grade students select areas of courses like social science and natural science and including students who selected the natural science might mislead the result. Therefore, there is a need for longitudinal studies that track and examine how students' epistemological beliefs would form during their high school years. Additionally, some studies reported that epistemological beliefs vary across high or low achiever schools (Acar, 2019; 2022). Students from five high schools were included in the study. There is a need for a more diverse and larger sample to determine the disciplinary differences in epistemological beliefs.

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Investigation of Secondary School Students’ Self-Efficacy for STEM Activities[1]

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Abstract

The STEM education approach aims to raise qualified individuals who can create global competitiveness. The high self-efficacy of the students in STEM disciplines will ensure that the goals are achieved smoothly. This research was aimed to develop a valid and reliable scale that can measure secondary school students' self-efficacy towards STEM activities. In addition, it was aimed to examine secondary school students' self-efficacy towards STEM activities in terms of different variables. The research, in which the survey design was used, was conducted with 786 (N1=445; N2=341) secondary school students. “STEM Activities Self-Efficacy Scale (STEM-ASES)” was developed, in which the $\chi2/df$ value and the model-structure fit perfectly and it fits well according to the CFI and TLI values with a reliability coefficient of (0.939). In addition, as a result of the research, it was stated that the secondary school students’ STEM activities self-efficacy scores did not show a statistically significant difference according to the variables of gender, school type, class level and frequency of technological use. However, it was stated that the students' self-efficacy in STEM activities differed statistically according to their achievement scores.

INTRODUCTION

The 21st century emerges as the era in which the world rotates much faster in scientific and technological terms. In order for countries to have a say in the international arena, they need to keep pace with the new world order both individually and socially. At this point, qualified workforce in different fields has become more important for nations (Karakaya & Avgin, 2016; Bahçepınar, 2023). As a matter of fact, when the main aims of education are examined, it is seen that it is aimed to raise individuals who follow scientific and technological developments and to develop creative, questioning, critical thinking and communication skills of these individuals (Timur & Belek, 2020). Both these important shifts in the targets of the countries and the changes in the target behaviors expected from the individuals have caused radical changes in the education systems and in recent years, an understanding of education that combines different disciplines such as science, technology, engineering and art has begun to be accepted (Aşılıoğlu & Yaman, 2020). In accordance with these developments, it is seen that many countries have made improvements, updates and radical changes in their education systems and curricula (Savran Gencer et al., 2019). When we look at the education system from the perspective of Turkey, it is seen that there have been significant changes in recent years. Especially when the science course curriculum is examined, it is seen that new approaches were adopted, and different learning outcomes were targeted by making some updates in 2005, 2013 and 2017 (MoNE, 2018). Çakıcı (2013) emphasized that with the changes made in the education systems of the countries, they plan to train students as "science/nature" personalities with scientific thinking skills. One of the educational arrangements made in this context is the integration of science, technology, engineering and mathematics with an interdisciplinary approach (Aşılıoğlu & Yaman, 2020; Karakaya & Yılmaz, 2022). Many Asian and European Union countries, led by the United States of America, have started to implement STEM (Science-Technology-Engineering-Mathematics) education at different school levels in order to create a social structure that is suitable for current approaches (Karakaya, 2021; Yılmaz et al., 2017).

Literature review

STEM education approach and its importance

The 21st century can be defined as an era in which many innovations and developments are integrated into human life. In this century, the need for individuals who can think critically and innovatively, know how to use technology while accessing information, who have high self-efficacy, are productive, inquisitive and understand technology has increased (Uluyol & Eryılmaz, 2015). Countries have added different technological applications to their programs by making updates in their education programs over the years. In the 2023 vision document published by MoNE, it sees its main goal as educating individuals with the knowledge and skills that it foresees to be needed in today's conditions and in the future, called 21st century skills (MoNE, 2018). The emergence and development of the STEM education approach were influenced by combining different disciplines (Sungur Gül et al., 2022) and the need of countries for a qualified workforce (Tekerek & Karakaya, 2018).

It is known that the concept of STEM was first used in history in 2001 by Judith A. Ramaley, who was the director of the Education and Human Resources department of the American National Science Foundation (Koonce et al., 2011). The National Science Association first used the expression "SMET" as the abbreviation of the initials of science, technology, engineering and mathematics disciplines, but this expression was later converted to "STEM" (Sanders, 2009; Er & Acar, 2020). STEM is a teaching approach that removes the barriers between science, technology, engineering and mathematics and suggests that all fields should be considered together (Wang, 2012). There are different explanations in the literature regarding the definition of the STEM concept. For example, Bybee (2010) defined STEM as an approach to make connections between different disciplines. Sanders (2009), STEM education is the collocation of multiple disciplines. According to Gonzalez and Kuenzi (2012), STEM is an interdisciplinary approach that covers all teaching processes from pre-school to higher education. STEM is to find solutions to the situations encountered related to the engineering field by using knowledge in science and mathematics disciplines with the help of the technology field (Kennedy & Odell (2014). According to Yıldırım (2013), STEM is an approach that keeps individuals’ dynamic for the learning field, enables them to reach their goals and reflect the knowledge they have learned to life.

Self-Efficacy for STEM Activities

Self-efficacy was first defined in the Social Cognitive Learning Theory put forward by Albert Bandura in 1977 (Bıkmaz, 2004; Ekici, 2009; Senemoğlu, 2007). Bandura (1986), defined self-efficacy as the thoughts belonging to the ability of the individual to make the necessary plans in order to achieve a situation and to put the necessary actions into practice in line with this plan. According to Senemoğlu (2007), self-efficacy is the individual's thoughts about himself in order to be successful in the face of possible difficulties that may arise in the future. In addition, self-efficacy can be defined as individuals' judgments about how successful they will be by managing their own performance (Holden & Rada, 2011). Considering the common points of these self-efficacy definitions, it can be concluded that self-efficacy is a person's belief in himself. As a matter of fact, even if individuals have sufficient knowledge and experience in a subject, if they have low self-efficacy beliefs that they will be successful, they are more likely to fail (Gawith, 1995). An individual's self-efficacy belief affects his perspective on work, the energy he will spend, his reaction according to whether the result is successful or unsuccessful, and what attitude they show in negative situations (Duman, 2017). Bandura (1977) stated that individuals with high self-efficacy behave differently and stated that the performance of the individual's behaviors can be predicted by looking at their self-efficacy status. The low self-efficacy of individuals causes them to be uneasy about the problems they encounter, to avoid dealing with them again when the desired result is not achieved, to experience insecurity, and to remain passive in their studies (Korkmaz, 2011).

In order to achieve the targeted gains in STEM activities, students' attitudes, awareness and self-efficacy towards STEM disciplines must be high. For STEM activities, self-efficacy perception is the belief that individuals have about the work plan of the activities they will do in STEM, the implementation of the application and whether the application can be evaluated or not (Karakaya & Yılmaz, 2022). If individuals want to acquire skills and competencies, self-efficacy should be supported (Akkoyunlu & Kurbanoğlu, 2003). Students' high self-efficacy in STEM may increase their interest in STEM subjects, may cause them to prefer STEM-related professions, and may also cause them to make academic choices about STEM (Sheu et al., 2010). Uğraş (2019) stated that the high self-efficacy and attitudes of students towards STEM fields also cause students' high interest in STEM professions. It is considered important that students have high self-efficacy in providing meaningful learning in STEM activities and in identifying and supplying the necessary materials (Hacıömeroğlu, 2020). STEM education is an approach that improves students' engineering skills and increases their academic success and interest in STEM professions (Katehi, Pearson, & Feder, 2009). From this perspective, it can be concluded that students' high STEM self-efficacy will increase their preference for professions in these fields. Achieving success in STEM depends on the high STEM self-efficacy of both teachers and students (Öztürk, 2019). Because individuals can use the knowledge of different disciplines together, create an exemplary model, and develop different models by blending their existing knowledge in engineering applications that they use while performing STEM activities with newly acquired knowledge (Yıldırım & Altun, 2015). While making these practices, individuals with high self-efficacy can reach their goals without giving up and relying on themselves.

The Purpose of Research

This research aimed to develop a measurement tool that can measure the self-efficacy of secondary school students towards STEM activities and to examine the students' self-efficacy in terms of different variables. This research focused on the variables of gender, school type, grade level, frequency of technology use and academic achievement score.

METHOD

Study Design

The scanning model was used in this research. According to Karasar (2006), the survey model is a system of surveys made on the population or a sample selected from the population in order to evaluate the population that contains many different variables in its structure. In addition, the survey model is research on a multi-component universe, the entire universe, or a sample taken from it in order to evaluate the universe as a whole.

Participants

In the 2022-2023 academic years, the research was carried out with the participation of students studying at different educational institutions. The institutions where the participants studied are located in a province in the Central Anatolia region of Turkey. The research, in which the appropriate sampling method was used, was carried out on a voluntary basis and taking into account the rule of "at least five times the number of items" (Tavşancıl, 2006) According to Büyüköztürk (2010, p.92), the convenient sampling method is; the preferred method because of its easy accessibility and applicability in cases where there are limitations in terms of time, financial opportunities and working conditions of the researcher. In this research, convenient sampling method was preferred in order to provide easy access to individuals. Descriptive statistics for the research groups are presented in Table 1.

Table 1. Descriptive information about the participants

		EFA group		CFA group	
Demographic Characteristic		N	%	N	%
Gender	Female	277	62.2	165	48.4
	Male	168	37.8	176	51.6
Type of school	State	303	68.1	233	68.3
	Private	142	31.9	108	31.7
Grade level	5	99	22.2	60	17.6
	6	110	24.7	57	16.7
	7	115	25.8	81	23.8
	8	121	27.2	143	41.9
Frequency of technology use	Sometimes	140	31.5	63	18.5
	Usually	230	51.7	202	59.2
	Very often	75	16.9	76	22.3
Achievement score	0-69	59	13.3	46	13.5
	70-84	155	34.8	97	28.4
	85-100	231	51.9	198	58.1
Total		445	100.0	341	100.0

As is seen in Table 1, 62.2% (N=277) of the students (N= 445) who participated in the exploratory factor analysis process of the research were female and 37.8% (N= 168) were male. A total of (N= 341) students, 48.4% (N=165) female and 51.6% (N= 176) male, participated in the confirmatory factor analysis process.

Data Collection

The development process of the scale is given in Figure 1. In the process of creating the item pool, the opinions of the teachers who actively applied STEM activities were taken. In addition, studies in the related literature (for example, Eroğlu & Bektaş, 2016; Evans, 2015; Hsu et al., 2011; Karakaya & Yılmaz, 2022) were analyzed. Afterward, a draft scale form consisting of 40 items was prepared that will enable to evaluate STEM activities from different perspectives. In order to create the form and ensure its validity some opinions were taken from experts working in different fields (2 academicians who are experts in the field of STEM, 1 Turkish expert to check their language skills and comprehension, and a teacher with a rich experience in actively doing STEM activities in this field). In accordance with the received opinions, six questions in the item pool were removed and a draft scale form consisting of 34 questions was created. In this research, a value of 0.32 was accepted as the lower limit of factor load in item selection with principal component analysis. Because 0.32 represents 10% of the variance explained by that item (Selçuk, 2019). It was decided when the items would be removed from the scale, based on the analysis results (item-total test correlation, exploratory factor analysis, Cronbach's α coefficient) and expert opinion. In co-items, the inclusion process of items with high correlation coefficients was followed. Items that did not meet the specified criteria were not included in the draft scale. After the items were removed, exploratory factor analysis was applied again to investigate the changes in the factor structure of the scale continuously.

Figure 1. Scale development steps

Data Anaylsis

The data obtained within the scope of the research were analyzed using a statistical package program. Skewness and kurtosis values were calculated for the assumption of normality of the data. According to the data obtained from the scale, the values of Skewness [-.527] and kurtosis [.155] were calculated. Tabachnick and Fidell (2013) emphasized that skewness and kurtosis values should be between ±1.5 in order to state that the data obtained in a study show normal distribution. Since the normality conditions were met, parametric tests were used in the data analysis of the research.

Ethics

Participants of this study were selected on a voluntary basis. In addition, they were informed both verbally and in written form that their data would only be used for scientific purposes. Anonymity was ensured by giving pseudonyms to the participants. In addition, the ethics committee approval was obtained before starting the study, and as a result of the audit, approval was obtained for the study with the report from Yozgat Bozok University Social and Human Sciences Ethics Committee' dated 19.10.2022 and numbered 37/26.

FINDINGS

In this section, the findings are presented respectively in accordance with the aims of the research. In the research, firstly, findings for developing a valid and reliable scale that can measure secondary school students' self-efficacy for STEM activities were given.

Development Findings of the Self-Efficacy Scale for STEM Activities

Item analysis and investigation of the factor structure of the scale

The item-total test correlations of 34 items in the draft scale form are given in Table 2.

Table 2. Item-total score correlation values of the draft scale

Item	Correlation Coefficients	Item	Correlation Coefficients	Item	Correlation Coefficients
I1	0.695**	I13	0.680**	I25	0.667**
I2	0.661**	I14	0.656**	I26	0.666**
I3	0.655**	I15	0.444**	I27	0.650**
I4	0.637**	I16	0.629**	I28	0.687**
I5	0.678**	I17	0.685**	I29	0.648**
I6	0.649**	I18	0.584**	I30	0.677**
I7	0.662**	I19	0.644**	I31	0.584**
I8	0.562**	I20	0.674**	I32	0.723**
I9	0.703**	I21	0.673**	I33	0.667**
I10	0.656**	I22	0.635**	I34	0.713**
I11	0.701**	I23	0.714**		
I12	0.656**	I24	0.543**		

*p<.05 **p<.01; I: Item

When the table was examined, it was seen that all items were within acceptable values. In this context, items with high correlation coefficients were determined from the equivalent items in the scale (1-9, 2-25, 3-29, 4-16, 7-19, 11-23, 14-27, 20-34, 22-30) and it was decided that they should be in the form of a scale. Within this framework, the draft scale form consisting of 34 items was reduced to 25 items. Before starting the analysis of the data in the scale, Kaiser-Meyer-Olkin (KMO) and Bartlett's sphericity test results were evaluated to see if the data structure was suitable for factorization.

Table 3. Results of KMO and Bartlett Sphericity Test

KMO		.963
Bartlett Sphericity	Chi square test	5080.967
	Degree of freedom	300
	Significance level	.000*

*p<.01

When the table is examined, the KMO coefficient was calculated as (.963) and the Bartlett test was calculated as [χ2=5080.967; p<.01)]. In the literature, for the KMO value, 0.60 (desired) was determined as the lower limit (Tabachnick & Fidell, 2013). Leech et al. (2005) defined the KMO value as "more than 0.80 is good, and higher than 0.90 is excellent for factor analysis". In the light of the results of the Bartlett sphericity test, it is possible to comment on the significant factorization of the data from the multivariate normal distribution and correlation matrix (Yurttaş Kumlu et al., 2017). It can be stated that the obtained data set is suitable for factor analysis.

EFA Results

The results obtained from the exploratory factor analysis (EFA) performed on the draft scale form (25 items) are given in Table 4.

Table 4. Factor analysis of the draft scale form and reliability results

	Factor Loads (EFA 1)			Factor Loads (EFA 2)		
Items	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
I6	.646			.637		
I7	.661			.654		
I8	.579			.591		
I9	.711			.715		
I10	.657			.655		
I12	.673			.677		
I13	.682			.685		
I14	.657			.651		
I16	.637			.642		
I17	.695			.708		
I18	.585			.594		
I21	.686			.688		
I23	.718			.724		
I25	.664			.659		
I26	.679			.680		
I28	.693			.699		
I30	.690			.696		
I31	.586			.587		
I32	.735			.740		
I33	.671			.678		
I34	.713			.726		
I3	.651		.383	-		
I5	.679		.323	-		
I15	.431	.717		-		
I24	.530	.444		-		
Eigenvalue (Total)	10.745	1.111	1.020	9.486	-	-
Explained Variance	42.981	4.445	4.078	45.170	-	-
Reliability (Cronbach Alfa)	0.944			0.939	-	-

When the table is examined, it has been determined that the draft scale form has a three-factor structure with an eigenvalue above 1.00. It was calculated that three factors with an eigenvalue greater than 1.00 explained 51,574% of the total variance. However, it was determined that some items gave load values to different factors (I3, I5, I15 and I24). For this reason, the relevant items were removed and EFA was performed again. When the literature is examined, if the variance explained by the first factor is 30% or more; it can be said that a scale has a one-dimensional structure (Büyüköztürk, 2010). The EFA results obtained within the scope of the research, the total variance explained by the first factor were calculated as 42.981%. It can be interpreted that the scale has a one-dimensional structure. In addition, the fact that the eigenvalue of the first factor is higher than the other factors also supports this interpretation. For this reason, I3, I5, I15 and I24 items were removed from the draft scale form and exploratory factor analysis was performed again. As a result, it was determined that the draft scale form had a single factor structure with an eigenvalue above 1.00. In addition, it was calculated that a single factor with an eigenvalue greater than 1.00 explained 45.170% of the total variance. The scree plot of the final form of the scale is given in Figure 2.

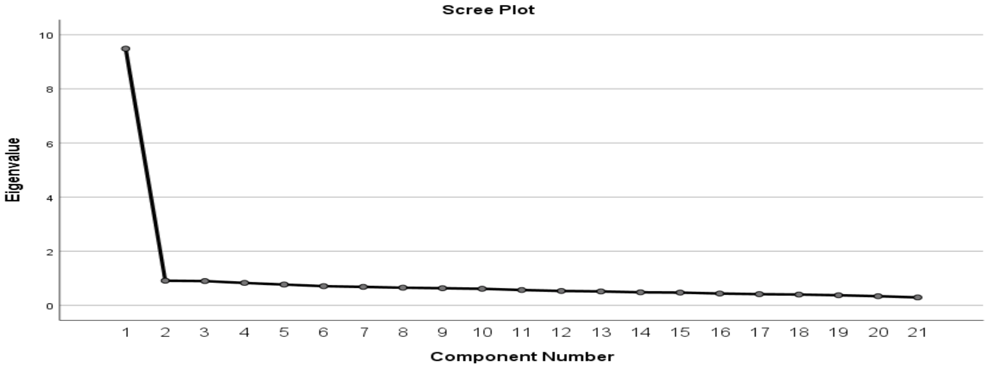
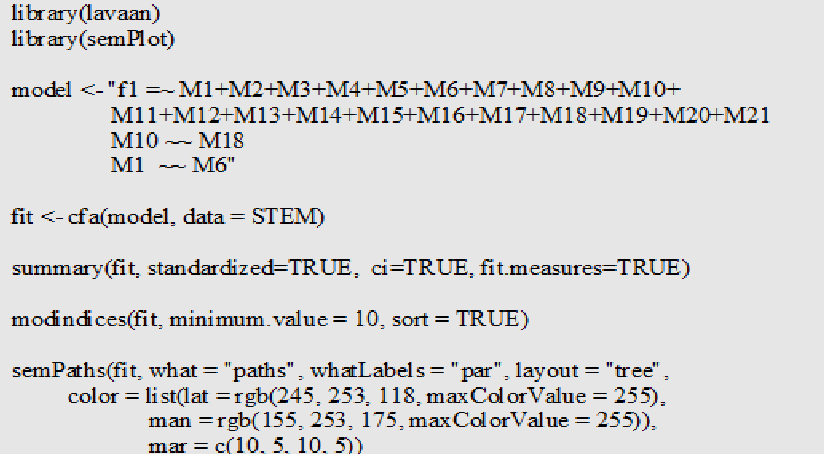


Figure 2. Eigenvalues of the components of the scale (scree plot)

CFA Results

Confirmatory factor analysis (CFA) was performed to verify the factor structure of the form obtained from EFA analysis. It was made using the lavaan (Rosseel, 2012) package over the R program. In addition, the semPlot (Epskamp, 2015) package was run for the image of the model. The R codes used in the analysis are given in Figure 3 and the standardized estimations of the model and variables (observed-implicit) established for the structure of the scale are given in Figure 4.



```
library(lavaan)
library(semPlot)

model <- "f1 =~ M1+M2+M3+M4+M5+M6+M7+M8+M9+M10+
              M11+M12+M13+M14+M15+M16+M17+M18+M19+M20+M21
              M10 ~~ M18
              M1  ~~ M6"

fit <- cfa(model, data = STEM)

summary(fit, standardized=TRUE,  ci=TRUE, fit.measures=TRUE)

modindices(fit, minimum.value = 10, sort = TRUE)

semPaths(fit, what = "paths", whatLabels = "par", layout = "tree",
       color = list(lat = rgb(245, 253, 118, maxColorValue = 255),
                 man = rgb(155, 253, 175, maxColorValue = 255)),
                 mar = c(10, 5, 10, 5))
```

Figure 3. R codes for Analysis (M: Item)

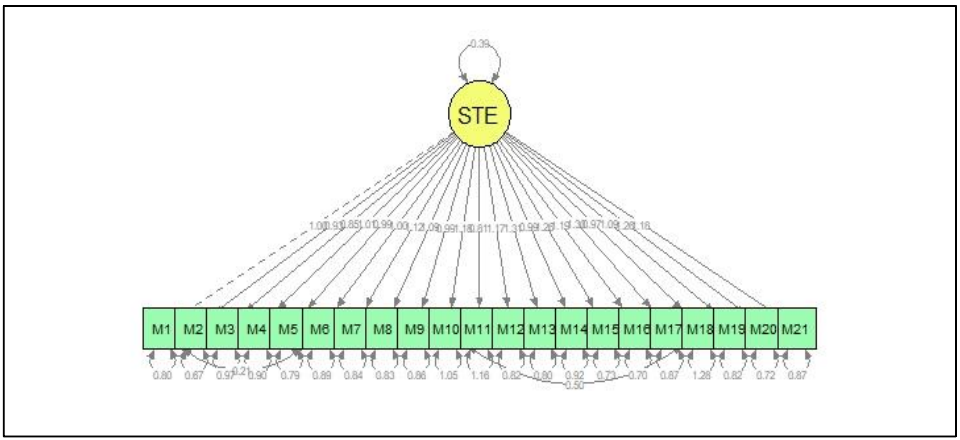
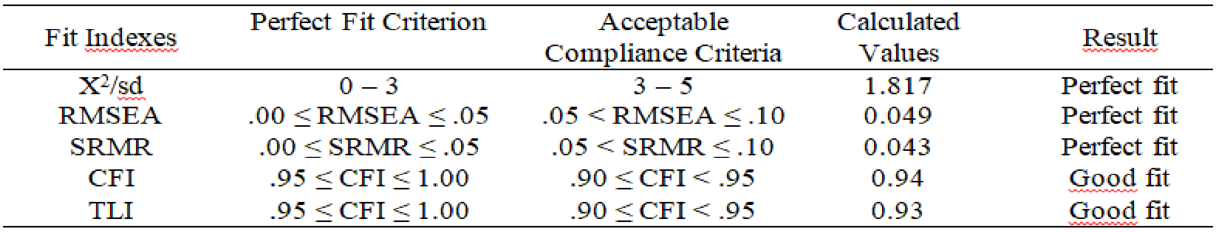


Figure 4. Structural equation modeling of the scale (M: Item)

When Figure 4 is examined, the structural equation modeling regarding the one-dimensional structure of the STEM Activities Self-Efficacy scale is seen. Error covariances were modified between the 1st and 6th items and the 10th and 18th items of the scale. In this way, new covariances were created for those with high covariance among the residual values of the items that reduced the fit of the model. The fit indices related to the results of the confirmatory factor analysis conducted within the scope of the research are given in Figure 5.



Fit Indexes	Perfect Fit Criterion	Acceptable Compliance Criteria	Calculated Values	Result
X^2/sd	0 – 3	3 – 5	1.817	Perfect fit
RMSEA	$.00 \leq RMSEA \leq .05$	$.05 < RMSEA \leq .10$	0.049	Perfect fit
SRMR	$.00 \leq SRMR \leq .05$	$.05 < SRMR \leq .10$	0.043	Perfect fit
CFI	$.95 \leq CFI \leq 1.00$	$.90 \leq CFI < .95$	0.94	Good fit
TLI	$.95 \leq CFI \leq 1.00$	$.90 \leq CFI < .95$	0.93	Good fit

Figure 5. Fit Indices for structural equation modeling of the scale

Since the RMSEA and SRMR values are between the desired values, the model-structure fit is perfect, It was determined that it showed good agreement according to CFI and TLI values.

Findings Obtained in the Analysis of Secondary School Students' Self-Efficacy on STEM Activities According to Different Variables

This research focused on the question *"Do the secondary school students' self-efficacy for STEM activities differ significantly according to demographic variables?"* In this context, the findings obtained from the sub-problems are given in order. In the research, the question to the "Do the secondary school students' self-efficacy towards STEM activities differ significantly by gender?" has been sought. The results of the one-way independent t-test analysis are given in Table 5.

Table 5. Results of one-way independent t-test analysis according to gender

Scale	Gender	N	$\bar{x}$	df	t	p
STEM-ASES	Female	165	76.20	339	1.085	.279
	Male	176	74.46			

*p<.05

When the table is examined, it was determined that the scores of secondary school students from the STEM activities self-efficacy scale (t($_{339}$)=1.085; p>.05) did not differ significantly according to the gender variable.

In the research, the question to the *"Do the secondary school students' self-efficacy towards STEM activities differ significantly according to the type of school?"* has been sought as well. The results of the one-way independent t-test analysis are given in Table 6.

Table 6. One-way independent t-test analysis results according to school type

Scale	Type of school	N	$\bar{x}$	df	t	p
STEM-ASES	State	233	74.83	339	-.854	.394
	Private	108	76.31			

*p<.05

When the table was examined, it was determined that the scores of secondary school students from the STEM activities self-efficacy scale (t($_{339}$)=-.854; p>.05) did not differ significantly according to the school type variable.

In the research, the answer to the question *“Do the self-efficacy of secondary school students towards STEM activities differ significantly according to grade level?”* has been sought. One-way analysis of variance (ANOVA) results are given in Table 7.

Table 7. ANOVA results for grade level

Factors		Sum of squares	df	Mean of squares	F	p
STEM-ASES	Between groups	818.409	3	272.803	1.239	.296
	In-group	74221.872	337	220.243		
	Total	75040.282	340			

*p<.05

When the table is examined, it is seen that the scores of secondary school students from the STEM activities self-efficacy scale [F($_{3,337}$)= 1.239; p>.05] did not differ significantly according to the grade level variable.

In the research, the answer to the question *"Do the secondary school students' self-efficacy for STEM activities differ significantly according to the frequency of technology use?"* has been sought. One-way analysis of variance (ANOVA) results are given in Table 8.

Table 8. ANOVA results on the frequency of technology use

Factors		Sum of squares	df	Mean of squares	F	p
STEM-ASES	Between groups	214.378	2	107.189	.484	.617
	In-group	74825.904	338	221.378		
	Total	75040.282	340			

*p<.05

When the table is examined, it is seen that the scores of secondary school students from the STEM activities self-efficacy scale [F($_{2,338}$)= .484; p>.05], it was determined that there was no significant difference according to the technology usage frequency variable.

In the research, the answer to the question *“Do the self-efficacy of secondary school students towards STEM activities differ significantly according to their achievement score?”* has been sought. One-way analysis of variance (ANOVA) results are given in Table 9.

Table 9. ANOVA results for achievement score

Factors		Sum of squares	df	Mean of squares	F	p	Tukey
STEM-ASES	Between groups	7005.022	2	3502.511	17.401	.000*	1<2 1<3
	In-group	68035.259	338	201.288			
	Total	75040.282	340				

*p<.05

When the table is examined, it is seen that the scores of secondary school students from the STEM activities self-efficacy scale [F($_{2,338}$)= 17.401; p<.05] differed significantly according to the success score variable. According to the results of the Tukey test, it was determined that there was a significant difference in the scores of the students whose achievement level was between (70-84) and (85-100) in the self-efficacy scale for STEM activities compared to the students who were in the range of (0-69).

CONCLUSION, DISCUSSION AND SUGGESTIONS

In this research, it was aimed to develop a measurement tool that can measure the self-efficacy of secondary school students towards STEM activities and to examine the students' self-efficacy in terms of different variables. As a result, the “STEM Activities Self-Efficacy Scale (STEM-ASES)” consisting of 21 items that can measure self-efficacy for STEM activities has been developed. The scale items were scored as "5 = strongly agree", "4 = agree", "3 = undecided", "2 = disagree" and "1 = strongly disagree". The draft scale form (34 items) prepared during the scale development process was created with the participation of 445 secondary school students. The draft scale form, in which the item-total score correlation values were calculated, was obtained by taking the opinions of the experts and a structure consisting of 25 items. EFA was conducted by considering 25 items. As a result of EFA, 4 items that loaded different factors were removed from the draft scale form and the scale form (21 items) turned into a single-factor structure. Cronbach Alpha of the scale form in this structure was calculated as 0.939. In addition, it was determined that it explained 45.170% of the total variance. The scale form for CFA was applied to 341 secondary school students who did not participate in the first study. As a result, the scale provided a high degree in terms of both fit indices and model-structure fit. The reliability coefficient of the final scale was calculated as 0.916. It can be claimed that the developed scale can be used to determine the STEM activities self-efficacy of secondary school students. When the literature on the subject is examined, it is seen that Özdemir et al. (2018) developed a one-dimensional scale that can be used to determine teachers’ self-efficacy for STEM applications. Additionally, Karakaya and Yılmaz (2022) stated that the scale they developed has a one-dimensional structure.

In the research, secondary school students’ self-efficacy for STEM activities was examined in terms of gender variable. As a result of the research, it was determined that the gender variable did not make a statistically significant difference in the self-efficacy scores of secondary school students for STEM activities. According to these results, it can be said that the gender variable is not a factor affecting secondary school students' self-efficacy for STEM activities. Indeed, Brown et al. (2016) concluded that there was no significant difference according to gender in the study they conducted with secondary school students on STEM self-efficacy. Dadacan (2021) found in her study that there was no significant difference between pre-service teachers’ self-efficacy regarding STEM teaching and their gender. Çevik et al. (2017) found that there was no significant difference between secondary school teachers' STEM awareness and gender. Aydin et al. (2017) stated in their study that there was no significant difference between students' attitudes towards STEM fields and their self-efficacy. In addition, in many studies on STEM, it is stated in the literature that the gender variable does not make a significant difference (Aşılıoğlu & Yaman, 2020; Özdemir & Cappellaro, 2020; Luo et al. 2021).

In the research, secondary school students' self-efficacy for STEM activities was examined in terms of school type variables. As a result of the research, it was determined that the school type variable did not make a statistically significant difference in the secondary school students' self-efficacy scores for STEM activities. According to these results, it can be said that the school type variable is not a factor affecting secondary school students' self-efficacy towards STEM activities. Ozyurt et al. (2018) in their studies investigating the attitudes of primary school students towards STEM, found that students' attitudes towards STEM differ in favor of students who go to private schools. However, in his study with middle school students, Bulut (2020) concluded that the STEM attitudes of the students did not differ according to the type of school. Aydin et al. (2017) compared the attitudes of public and private school students towards STEM in their study with secondary school students. As a result of the research, they determined that there was no significant difference between the attitudes of students attending public and private schools towards STEM. Karakaya et al. (2018) stated in their study with science teachers that there is no significant relationship between the type of school they work in and their awareness of the STEM education approach. Similarly, Şahin (2019) mentioned in her study that the professional competencies of teachers regarding the STEM education approach do not change according to the type of school they work in.

In the research, secondary school students' self-efficacy for STEM activities was examined in terms of grade level variables. As a result of the research, it was determined that the grade level variable did not make a statistically significant difference in the self-efficacy scores of secondary school students for STEM activities. According to these results, it can be said that the grade level variable is not a factor affecting secondary school students' self-efficacy for STEM activities. Gök (2022), in his study with secondary school students, found that students' attitudes towards STEM did not change according to grade level. In their study with BİLSEM students, who go to secondary school, Bircan and Köksal (2020) concluded that grade level does not statistically affect attitudes towards STEM disciplines. Balçın, Çavuş, and Topaloğlu (2018) stated in their study with secondary school students that there was no significant difference between students' grade levels and their attitudes towards STEM. However, unlike the research result, Unfried et al. (2014) found in their study with secondary and high school students that as the grade level increased, students' attitudes toward STEM increased positively.

In the research, secondary school students' self-efficacy for STEM activities was examined in terms of technology use frequency variable. As a result of the research, it was determined that the technology use frequency variable did not make a statistically significant difference in the secondary school students' self-efficacy scores for STEM activities. According to these results, it can be said that the variable of frequency of technology use is not a factor that affects secondary school students' self-efficacy towards STEM activities. As a matter of fact, Tekerek and Karakaya (2018) determined that there was no significant difference between pre-service science teachers' STEM awareness and the frequency of technology use. Demirtas and Eksioglu (2020) examined the relationship between pre-service teachers' STEM awareness and the level of information and communication technologies use. As a result of the research, they determined that there is a positive, significant but weak relationship between pre-service teachers' STEM awareness and their use of information and communication technologies.

In the research, secondary school students' self-efficacy for STEM activities was examined in terms of achievement score variable. As a result of the research, it was determined that the success score variable made a statistically significant difference in the self-efficacy scores of secondary school students for STEM activities. It was determined that the students in the range of achievement (0-69) had lower self-efficacy towards STEM activities than the students in the range of (70-84) and (85-100). According to these results, it can be said that the level of achievement is a factor that affects secondary school students' self-efficacy towards STEM activities. Bulut (2020) determined that the STEM attitudes of the students who have a success average between 70-84 and 85-100 differ significantly compared to the students with a success average of 1-50. In addition, in the study, it was determined that the STEM attitudes of the students with a success average of 70-84 and 85-100 differed significantly compared to students with a success average of 51-69. In her study, Dadacan (2021) concluded that there was no significant difference between pre-service teachers' self-efficacy regarding STEM teaching and their academic achievements.

Suggestions

As a result, it is important to carry out practice-oriented activities to improve secondary school students' self-efficacy for STEM activities. Examining the variables affecting students' self-efficacy in detail with their reasons is considered significant for the future of the practices.

Declaration

This research was produced from the master thesis completed by the first author under the supervision of the second author, which was completed in May 2023 at Yozgat Bozok University. Additionally, this study was presented as an oral presentation at the 14th Congress on New Trends in International Education.

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Annex-1 STEM Self-Efficacy Scale (Final Scale Form)

İtem Number	**STEM Activities Self-Efficacy Scale (STEM-ASES)**
1	I can create questions to evaluate the produced model.
2	I can identify problems in STEM activities.
3	I can use technological tools in STEM activities.
4	I can test whether the model I produced works.
5	I can develop projects using STEM activities.
6	I can evaluate the produced model in terms of usefulness
7	I can decide on the tools and equipment I will use in STEM activities.
8	I can develop multiple solution suggestions in STEM activities.
9	I can prepare a sample design for the solution of the problem in STEM activities.
10	I can do group work in STEM activities.
11	I can calculate costs in STEM activities.
12	I can tell you the shortcomings of the produced model.
13	I can list needs in STEM activities.
14	I can decide on the best solution in STEM activities.
15	I can use STEM activities in my projects.
16	I can check whether the model produced is fit for purpose.
17	I can explain the features of the developed product.
18	I can decide my model with my friends.
19	I can evaluate the produced model in terms of providing a solution to the problem.
20	I can evaluate the produced model in terms of efficiency.
21	I can fix the deficiencies in my model.

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[1] This study was produced from the master thesis completed by the first author under the supervision of the second author, which was completed in May 2023 at Yozgat Bozok Universite. Additionally, this study was presented as an oral presentation at the 14th International Congress on New Trends in Education.

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Investigating Science Student Teachers' Use of Instructional Technologies

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Abstract

The aim of this study is to investigate science student teachers' technology preferences and how they value technology in their teaching practices. This study employs the instrumental case study design which is one of the types of case study strategies. The study was carried out with the participation of eight volunteer science student teachers (3 males and 5 females) in the science education department of a state university in the spring term of the 2018-2019 academic year. Data were gathered by observing student teachers' actual teaching during teaching practice and collecting their documents from reflective journals and lesson plans. Data were analyzed inductively, using thematic analysis. The results showed that science student teachers used some technological tools categorized as instructional hardware, instructional media and instructional software during their teaching practice. The values that participating student teachers attributed to the tools used were two-fold: 'supporting the teaching process' and 'surviving in the classroom environment'. However, the study also showed that the participants mainly used technological tools in their teacher-centered activities.

INTRODUCTION

With the introduction of computer technologies into education, computer technologies are used mainly by teachers as a means of preparing plans, conducting searches for information, presenting information, preparing exam questions and communicating (Roblyer & Doering, 2007; Zyad, 2016) rather than being used for teaching purposes (Starkey, 2020). The projects that pave the way for the use of instructional technologies in schools lead to the use of smart boards in learning environments and the review of teacher competencies (Akyüz et al., 2014). With the widespread use of interactive whiteboards, the use of computer technologies emerges as a basic ICT (Information and Communication Technologies) competency for teacher candidates (Hammond et al., 2011; Kayaduman et al., 2011). Smart boards, which are used with programs that allow the use of teaching presentations such as formulas, pictures, maps, figures, animations and videos that can be used in teaching, also offer the opportunity to access various materials via an internet connection. These boards, which are seen as the combination of white and blackboards in the traditional classroom environment with computer technologies, are seen as one of the educational technologies that help improve the quality of learning and teaching (Jang ve Tsai, 2012; Roblyer & Doering, 2007).

Because educational technologies make learning environments interesting, increase permanence by appealing to more senses, make abstract concepts concrete and facilitate the teaching of difficult or dangerous situations, teachers are expected to use educational technologies such as mobile applications, augmented and virtual reality, robotics and coding, animations, simulations and Web 2.0 applications effectively during their teaching, (Jang, 2008; Wojciechowski & Cellary, 2013). Since science courses include abstract topics such as micro-scale heat and temperature, electricity and magnetism, these technologies are expected to be used in lessons to make what is learned concrete (MNE, 2018). With computer-based instruction, which includes interactive computer presentations, visuals such as graphics and pictures, videos, applications providing audio feedback and simulations used in the classroom environment, it is aimed to create curiosity in the learners about scientific subjects and to make learning fun (Güven & Sülün, 2012). In addition, the computer-based teaching method, which allows learning environments such as problem-solving, repetition and practice, simulation, animation and interactive presentations for expensive or dangerous experiments, contributes to making the achievements of the science course more understandable for students. This method is also used to gain positive perspectives toward science in addition to developing professional knowledge areas such as learning and consolidating content knowledge. Because of these gains and objectives, it is important to train equipped student teachers with technology skills and knowledge through teacher-training programs to meet expectations in the 21st century (Batane & Ngwago, 2017).

Research on the use of technology by teachers showed that teachers mainly prefer to make use of technology in a teacher-centered manner rather than student-centered activities (Hu & Yelland, 2017; Tondeur et al., 2012; Voet & De Wever, 2017). Hu and Yelland (2017) pointed out that when student teachers used technology in their classroom, they generally originated and directed the majority of the activities instead of letting their students find their way out. Voet and De Wever (2017) emphasized that since teachers generally see technology as a resource for their teaching activities rather than as tools students actively could use, they do not give students enough opportunities to use technology (Voet & De Wever, 2017). However, it is worth noting here that as Liem et al. (2014) stressed, the way students use technology is more crucial than how much they use these tools to utilize their problem-solving skills in their learning. This means that teachers' pedagogical reasoning and critical decision-making on the integration of technology into classroom teaching is crucial (Harris & Phillips, 2018; Hofer & Harris, 2019). For example, Hughes et al. (2020) also examined teachers' reasoning for using technologies and their results showed that student teachers designed mainly teacher-centered teaching activities rather than student-centered and their reasons to use technology in their teaching were about its potential presentational and engagement effects. However, they stressed that in-service teachers designed student-centered activities to support student learning through technology. Baek et al. (2008) identified six factors influencing teachers’ choices of employing technology in their teaching such as ‘adapting to external requests and others’ expectations, deriving attention, using the basic functions of technology, relieving physical fatigue, class preparation and management, and using the enhanced functions of technology’ (p. 228). They concluded that experienced teachers’ decisions were affected by external forces while less experienced ones integrated technology into their teaching on their own will even though all tended to make use of technological tools.

In Turkey, the studies on the use of computer technologies in education are on various subjects such as the effect of technology use on achievement and attitude (Bilir & Uyanık, 2019; Dağdalan & Erol, 2017; Şahin & Namlı, 2019; Tekdal & Ilhan, 2021), student teachers' and teachers' competencies in using technology (Gökal et al., 2020; Kocasaraç, 2003) and opinions of teachers or student teachers on using technology in their lessons (Bıçak, 2019; Çelik & Karamustafaoğlu, 2016; Timur & Özdemir, 2018; Yılmaz, 2020), self-efficacy (Simsek & Yazar, 2019) and tendencies (Tanık-Önal, 2017; Yenice et. al. 2019). It seems that studies of teachers' technology use in Turkey have been based on their statements or self-reported, which is a crucial limitation of the studies on this topic (Starkey, 2020). Considering that most of the schools have basic technological tools in place, investigating teachers' use of them in their classrooms will give more realistic information about how they value technology in their teaching. At the end, teachers are to decide the way to integrate these valuable tools into their teaching (Tsai & Chai, 2012).

The Purpose of Study

The aim of this study is to investigate science student teachers' preferences and how they value technology in their teaching practices. For this purpose, answers to the following questions were sought.

1. Which types of technology do science student teachers prefer to use in their teaching?
2. How do they value their use of technology in their teaching?

METHODOLOGY

Study Design

This study employs the instrumental case study design which is one of the types of case study strategies (Stake, 1995). As Creswell et al. (2007) stated, in the case study as a methodology within the qualitative research approach; the researcher explores a bounded case or cases over time through methodological triangulation (use of multiple data collection techniques). The purpose of this study is to investigate the type of technology that science student teachers use during their teaching practices and the value they attach to technology use. Therefore, the focus of this research is on their use of technology rather than the cases themselves; as Stake (1995) points out the cases selected are instrumental to provide insight into research concerns.

Participants

The study was carried out with the participation of eight science student teachers (3 males and 5 females) in the science education department of a state university in the spring term of the 2018-2019 academic year. The participants were volunteers to take part in this study and they were selected by using convenience sampling technique. The participants attended their teaching practice in the last semester of their teacher training program to form a basis for teaching experience under the guidance of two supervising science teachers and a university supervisor.

Data Collection

In this study, observation and documents (student teachers' reflective journals and lesson plans) were used as data collection techniques, further explained in the following part.

Observation: As Patton (2002) stressed, using observation in research provides the researcher with personal knowledge including his or her reflections and introspections during the data analysis process. In the current study, the participating science student teachers' teaching practices were observed across three different topics within science curricula. These observations provided opportunities for the researchers to describe the setting and to understand the actual role and use of technology in the participants' teaching. As a marginal participant the researcher was in a passive role; that is, sitting at the back of the class, observing student teachers' teaching and taking field notes related to research concerns.

Reflective journals: Reflective journals are quite useful tools in educational research (Bashan & Holsblat, 2017; Phelps, 2005) and teacher training programs (Clarke, 2004; Phelps, 2005; Zulfikar & Mujiburrahman, 2018); that is, they are used as data collection tools in educational research and as tools to promote learning through their reflections. From the research perspective, reflective journals are valid tools to collect powerful qualitative data, the practitioners' insights that might be hard to document in using other methods of data collection (Phelps, 2005). Indeed, the reflective practice is part of teacher training, especially throughout the teaching practice (Cengiz, 2020). In this study, the participating science student teachers were asked to reflect on their teaching in an unstructured manner, regarding technological tools they used, their planning, methods, timing, class management and personal thoughts. Their journals were collected and stored for analysis. In gathering their reflections, the objective was to understand why and how they use technological tools and how they value their uses.

Lesson plans: A lesson plan is an organizer tool that teachers develop to map what should be taught and how this teaching would take place in the process throughout the course of time (Kubilinskiene & Dagiene, 2010). Here in this study the participants were responsible for preparing a lesson plan before each lesson they taught, which was a task for student teachers to master during their teacher training. Again, the objective of gathering data through lesson plans is to understand the purpose, role and stage of the participants' use of technology in their planned teaching.

Data Analysis and Trustworthiness in the Study

Data from different sources like field notes, lesson plans and reflective journals, were analyzed concurrently after data collection was completed. As a type of thematic analysis, inductive thematic analysis was employed in this study. Inductive thematic analysis is an iterative process of deriving meaning from qualitative data inductively through emerging themes (Braun & Clarke, 2006). In this study, to analyze the data Braun and Clarke's six steps were employed thoroughly. First, the data from all three datasets were read repeatedly and some comprehension notes were taken in the left margins of the text. This was the part of writing starting at this first stage of analysis and continued throughout the work, and the relevant chunks of data were colored at this stage. Doing this provided the researcher with a generic understanding of and familiarization with the whole dataset.

Second, the data were coded using the right margins of the texts, while remaining descriptive; that is, the extracts of data were coded at the semantic level rather than the latent level (Braun & Clarke, 2006). At this stage of the analysis, an initial code list or template was created as a result of both researchers' independent coding of the data obtained from the first case after a thorough discussion over the first level codes. Using this template for the next cases, the newly emerged codes were added to the code list or template with the same discussion process. The aim was to reach a framework which was the final version of the template. The framework was the end product of both researchers' coding and discussions. By doing so, seven first-level codes for the tools used by the participating student teacher and 19 first-level codes for the value the participants attached to their use of technology were identified. At this stage, both researchers also took some notes, including potential themes using the left margins again.

The third step in the analysis process was to search for the potential themes, taking the first-level code list or framework and left margin notes into consideration. This was achieved through collating first level codes into potential themes and selecting related extracts under each potential theme (Braun & Clarke, 2006).

Almost along with the third step, a theme map was created by reviewing the potential themes in the fourth step of the analysis process. Later, it was preferred to present this theme map as a table (Tables 1 and 2). At this stage, sub-themes and themes were determined and clarified.

The fifth step in the analysis includes naming and defining the themes. In order to ensure the theme map created in the fourth step, all datasets were reviewed in this step and it was ensured that the themes explained the structure within the data. At this stage, sub-themes and themes were named and the final version of the theme map was turned into a table.

And, finally a research report was produced under the themes and sub-themes that emerged in the study. At this stage, necessary associations were tried to be made in line with the objectives of the research and it was proved with direct quotations depending on analytical interpretations.

Researchers have taken some measures to ensure the trustworthiness of this study. Rather than calculating inter-coder reliability, the two researchers had discussion over the coded data, first-level codes, sub-themes and themes to ensure consistency until a full agreement was achieved. The two researchers' collaboration was in place throughout the whole research process, from designing the research process to reporting findings. It is worth noting here that the researchers have tried to be reflexive on their role throughout the study. The data collection process continued for an academic term, and the researchers were constantly present and communicating with the participants at school and at the university during this period. This prolonged involvement is an important measure to increase the credibility of research results (Lincoln & Guba, 1985; Denscombe, 2007). In this process, it was tried to provide participant control by giving feedback about the early evaluations of the collected data. This was an opportunity for member-checking, which is one of the crucial measures for the credibility of the study (Lincoln & Guba, 1985; Miles & Huberman, 1994). Using multi-methods to collect data was also a crucial measure for increasing both the credibility and dependability of the research (Lincoln & Guba, 1985). For proving the credibility and confirmability, the findings were supported by sufficient direct quotations from the participants in the study.

FINDINGS

In this section, findings are presented on which technological tools student teachers use during their teaching practices and what value they attribute to the use of technology. The findings obtained from the analysis of the data collected through the participating student teachers' lesson plans, reflective journals and observations are shown in Table 1 and Table 2.

Types of Technology Being Used in Teaching Practice

It is worth noting here that the aim of this part is to find answers to the first research question about what technological tools the participating science student teachers use during their teaching practice. The findings showed that science student teachers used technological tools in the categories of instructional hardware, instructional media and instructional software during their teaching practice. This categorical classification is based on Hughes et al. (2020) study.

Table 1. Technological tools used by science student teachers in their teaching practices

	Categories	Tools
Technological tools to be used	Instructional hardware	Smartboard
		Computer
		Printer
	Instructional Software	Drill and Practice
		Simulation
		Animation
	Instructional Media	Video
		Image

As seen in Table 1, the participant science student teachers frequently used the smart boards available in all classes in the instructional hardware category. In this category, it was also revealed that they used computers and printers especially in the preliminary preparations they made before teaching. It was observed that they used the worksheets they produced using these instructional hardware tools for evaluation purposes during their teaching. Data analysis revealed that the participants made use of animation, simulation and drill and practice applications which were classified under the category of instructional software. While the students participated in the teaching more actively in the drill and practice tools, the other tools were included in the teacher-centered practices. On the other hand, findings showed that the participating student teachers used images and videos which were classified under the instructional media category to promote students' learning.

The findings show that except for one student teacher, other pre-service teachers used technological tools in their teaching. However, this student teacher's reflective journal revealed her thoughts on the necessity of using technological tools after teaching as illustrated in the following extract:

> *If I taught the lesson one more time, I would benefit from the videos from EBA [Educational Information Network]. Students focus better on the information in the video (PST4, reflective journal).*

In the following part, findings about how the participants value their use of technological tools in their teaching were presented.

The Value Attributed to the Use of Technology in Teaching

The analysis of the data revealed the value that student teachers attributed to the use of technological tools in their teaching with two themes: 'supporting the teaching process' and 'surviving in the classroom environment'.

Table 2. Student teachers' values to use instructional technologies

Themes	Categories	Codes
Supporting teaching process	Increasing the efficiency of teaching	Reiterating Ensuring persistence Reinforcing Summarizing Visualizing Solving questions Evaluating Associating with daily life
	Enhancing students' learning interest	Motivating Attracting students' attention Arousing curiosity Making students think
	Presenting	Appealing to more senses Not understanding the drawing on the board Supporting the lecture Making things concrete
Surviving in the classroom environment		Avoiding wasting time Gaining time to cover the subject Spending time

Table 2 shows these two themes and their associated categories and codes.

Supporting Teaching Process

As can be seen in Table 2, it is revealed that student teachers mainly use instructional technologies to support their teaching process. This theme states that to improve their teaching quality, science student teachers use the opportunities offered by technology to support students' learning. Under this main theme, three categories emerged as enhancing learning interest, presenting and increasing the efficiency of teaching. These categories are detailed below, respectively, under subheadings.

Increasing Efficiency of Teaching

It is seen that the use of instructional technologies by student teachers was to support their teaching process to increase the effectiveness of their teaching. This category refers to the selection and use of appropriate technology in realizing students' conceptual learning. The participants think that reiterating, summarizing, using various assessment activities, visualization and associating with daily life will contribute to the permanence and reinforcement of students' learning.

Some student teachers stated that reiterating and summarizing would provide permanence and would be important in consolidating the subject. Reiterating and summarizing the topic being taught were achieved through making use of different technological tools. The following excerpts illustrate some student teachers' views on how they value the tools employed in their planning and actual teaching.

> *I think that summarizing the lesson by watching a video is effective in concretizing the subject (PST$_3$, reflective journal).*

> *I believe that students' learning was reinforced by watching the video of metamorphosis using the summary of the subject available in Morpa campus. By visualizing the topic, I ensured permanent learning in students (PST$_3$, reflective journal).*

It has been determined that student teachers generally use activities such as summarizing and reiterating the topic being taught during the elaboration phase of the course by using instructional technologies like video to reinforce what has been learned and ensure permanence as indicated in the following extracts:

> *I did not use a video to provide information in the explanation phase; I preferred to provide the information myself. I used the video as a reinforcer during the elaboration phase. I thought that the children would reiterate what they heard from me watching the video (PST$_8$, reflective journal).*
>
> *I preferred to use video to deepen the information and ensure permanent learning (PST$_8$, lesson plan).*
>
> *In the elaboration phase, I preferred to use video, that is, computer-assisted instruction, on the subject. I thought that this would reinforce students' learning (PST$_5$, reflective journal).*
>
> *I aimed to ensure permanence by using a documentary video about fish giving birth during the elaboration phase (PST$_2$, reflective journal).*

It is worth stressing here that the participating student teachers prepared their lesson plans considering the 5E learning model which was their own preference. However, their use of technology was mainly in teacher-led activities contrary to what is expected in the 5E learning model. On the other hand, in the evaluation phase of their lesson plan and actual teaching, it is aimed to reach more question types by using computer technologies, to solve questions and to increase the effectiveness of learning through evaluation activities as you can see in the following extracts:

> *I used the activities in EBA in the evaluation to reach various questions such as concept maps and filling in the blanks in the puzzle (PST$_8$, reflective journal).*
>
> *After completing the activities in the book, I used the activities I prepared from the smart board in evaluation (PST$_7$, reflective journal).*
>
> *In the evaluation, questions will be solved for practice purposes on electrically charged objects from Morpa campus (PST$_5$, lesson plan).*

It has been revealed that some student teachers used technology to increase the effectiveness of teaching through visualization as PST$_1$ stated:

> *I chose computer-assisted teaching in order to add appeal to the subject and to ensure better retention in their minds (PST$_1$, lesson plan).*

Finally, in the effectiveness of the teaching, it was determined that most of the participants benefited from computer technologies in order to associate the topics covered with daily life.

For example, PST_1 showed the students the events such as the formation of the rainbow and seeing the mirage by making associations with daily life after his own explanation of the topic refraction of light, through videos, expressing that:

> *During the elaboration phase, I will explain it on the board in a way they can understand and have them take notes in their notebooks. Then I will show you videos on the subject from EBA such as the formation of a rainbow, puddles on an asphalt road or under trees in the desert in very hot weather (PST_1, lesson plan).*
>
> *I think it [using technology] is good because it is effective in concretizing the lesson by watching the video… (PST_3, reflective journal).*

Enhancing students' learning interest

Within the scope of this category, student teachers stated that they used technological tools to attract students' attention. They stressed that they use some technological tools in teaching because of their features that increase students' motivation, attract attention, arouse curiosity and make them think.

> *In the introduction, I used a video because I thought videos would attract the attention of the students. I asked open-ended questions about the video (PST_5, reflective journal).*
>
> *To arouse curiosity, I showed the picture on the smart board to the class and asked them, 'What do you see in this picture?' My aim here was to make students think when they look at the picture, to arouse curiosity, to draw attention to the lesson and to provide motivation (PST_6, reflective journal).*

Although technological tools used to attract attention are generally preferred at the introductory stage, they are used to ensure students' motivation during the course as some participants stressed in the following extracts.

> *I will use videos and visuals to help them adapt to the lesson without getting bored (PST_1, lesson plan).*
>
> *If I had done the revision instead of using the video, the students would have gotten bored (PST_8, reflective journal).*

Presenting

Most of the student teachers stated that they used technology for the presentation of the content in their teaching. They stressed that visuals and videos appeal to more senses, that ready-made visuals are more effective than drawings made on the blackboard by the teacher, that they help to concretize events that cannot be observed in the classroom environment, and that they help support their own teaching. The majority of the candidates preferred instructional technologies because they appeal to different senses as can be seen in the following extracts:

> *In order to reinforce what I was telling, I showed them a video during the elaboration phase to make it appealing to the eye and ear (PST_8, reflective journal).*

> *I preferred to use video because it appeals to more sense organs (PST$_8$, reflective journal).*

PST$_1$ emphasized that they should benefit from computer technologies in order to provide students with a better version of the presentations they make in the classroom environment. While explaining the structure of the ear, PST$_1$ stated in her post-teaching reflective journal that the shapes he drew on the board could not be understood by the students because they were not very good, so he should benefit from instructional technologies, stressing that:

> *I drew on the board in the explanation stage but the students did not understand my drawings. This was also a waste of time. I had to benefit from the smart board (EBA) on this issue (PST$_1$, reflective journal).*

In addition to the different strategies and methods used by student teachers for their teaching, they used computer technologies and emphasized the aim of supporting their teaching by visualizing information as can be seen in the following extracts:

> *I employed an argumentation method during the exploring phase. After explaining the topic on the board during the explanation phase, I showed a video for real visual support (PST$_7$, reflective journal).*
>
> *In the explaining phase, I talked about the event and provided the missing parts. In this phase, I wanted to provide support by using a video on the subject... After the activity, I had the students take notes. The video supported the topic (PST$_5$, reflective journal).*
>
> *I showed by a video that lenses cause forest fires and that we should be careful. In addition, my explanations, I supported them with video and visuals and made them see the moment of fire (PST$_3$, reflective journal).*

Surviving in the classroom environment

While most of the student teachers preferred computer-assisted instruction to support the teaching process, some of them used it to overcome the difficulties they encountered in the classroom environment due to their first experience in teaching. They preferred technological tools for reasons such as using time effectively, filling time, saving time, and finishing the topic on time. It has been observed that candidates receive help from computer technologies in unexpected situations they encounter during teaching. For example, PST$_1$ stated in her reflective journals that the drawings she made on the blackboard took time; instead, it would be more beneficial to use the visuals on the smart board in terms of time. Class observations show that PST$_2$ uses computer technologies to fill the time in the remaining part of the lesson because he finished the topic unexpectedly early. Similarly, PST$_6$ applies instructional technologies to eliminate the problems encountered while performing its planned experiment on germination and PST$_7$ used the smart board for the remaining time because his activities end earlier than planned. The participants also explained these situations during their teaching in their reflective journals as can be seen in the following extracts.

> *I used question-answer and lecturing techniques in the explanation part. Additionally, I received support from EBA... There were problems in germination activity, but even if there were no problems, a clear result would not be obtained*

> *as germination would take 1-2 weeks. I overcame this situation by using a video from the first lesson (PST_6, reflective journal).*
>
> *I didn't have any shortcomings for this course other than being a little late to the class. I got over this by finding an easy solution thanks to the smart board (PST_7, reflective journal).*

On the other hand, the PST_2 did not turn on the smart board from the beginning, later in the lesson asked for help on this issue since she did not know what was in the videos. In her lesson plan there was no sign of computer assisted instruction on sexual and asexual reproduction topics, but since the lesson was explained and finished very quickly, she used videos in the exploration phase of the second lesson to cover the rest of the class time.

The findings show that all participating science student teachers, except PST_4, used computer-assisted teaching in their teaching practice and PST_1 and PST_6 used computer-assisted teaching methods in teaching other subjects except one. However, PST_4, who did not plan to use technology in her lesson plans, did not use technology at all during teaching, emphasized her thoughts on the need to include technological tools in teaching in her reflective journals after his teaching experiences as can be seen in the following extract:

> *If I were to plan the lesson again, I would make use of a video in the explanation phase. Students focus well on things in the videos (PST_4, reflective journal).*
>
> *Findings show that the majority of participating science student teachers use technology to manage lesson time to survive in their first teaching experiences.*

DISCUSSION AND CONCLUSION

This study, which aims to determine science student teachers' use of technology in their teaching practices and which value they attribute to technology, has revealed that the majority of student teachers include computer-assisted teaching in their teaching plans and practices. However, Batane and Nikivago (2017) stressed that student teachers did not use technology in their teaching activities even if they had the skills and knowledge to use different technological tools. In this study, only one of the participating student teachers did not include ICT in her lesson plans and teaching. She expressed her need for ICT use and the contributions of ICT to teaching after her teaching experiences in her reflective journals. This is similar to that of Tondeur et al. (2012) result indicating student teachers' use of technology depends on their motivation to integrate technology into their teaching, and thus some do and others do not. In the study of Tatlı et al. (2017) at the end of a training program, all student teachers emphasized the necessity of using technology in the classroom environment. However, their use of technology is mainly for presentation and communication. As Starkey (2020) stressed educators do not integrate technology into their teaching as expected from them even though they have the competence to use certain technologies.

Findings revealed that the participating student teachers who made use of technology in their teaching preferred to use tools such as drill and practice activities, animations, simulations, videos, visuals, smart boards, computers and printers. A similar finding is found in the study by Hughes et al. (2020). They found that student teachers use technological tools such as smart boards, printers, videos and visuals during their teaching, the in-service teachers, on the other hand use the drill and practice and animation tools within the scope of instructional software, not the in-service teachers. Similarly, in the study of Hammond et al. (2011), smart boards were central to nearly all students' practices. This study also showed that the participating science student teachers made use of technological tools supporting their own teacher-centered activities during their teaching.

One of the emerging themes about the participants' value of their use of technology during their teaching was 'supporting teaching process', which includes three categories such as increasing efficiency of teaching, enhancing students' learning interest and presenting. The other theme is 'surviving in the classroom environment'. Similarly, in Ipek Akbulut's (2016) study, it was stated that science student teachers make use of technology as a means of supporting the teaching process through presentation, attracting student attention, and increasing teaching effectiveness. Baek et al. (2008) showed that the reason why teachers, most of whom are in primary schools and some are in secondary schools, use technology is not for the learning and teaching processes, but for the purpose of meeting the expectations of the students and the society. Johnston and Suh (2009) found that pre-service elementary teachers integrated technology into their teaching based on whether it was fun or not, rather than whether it supported conceptual understanding. However, in this study it was found that student teachers mainly use computer technologies for presentation purposes to support the teaching process, and this is common in different studies (Aslan & Zhu, 2017; Hughes et al., 2020; Polly, 2014). Hughes et al. (2020) stressed that the values teachers attributed to the technology use were about students' knowledge development while student teachers tended to value the use of technology as a tool for presentation and students' engagement. In this study, it was seen that some of the student teachers also use technology in teaching to survive during teaching as practitioners. Here, the participating student teachers expressed that technology is their life-saver when they have problems in planning lesson time, either to create time or to save time.

The themes that emerged as a result of the analysis of the data obtained within the scope of both research questions are more limited in terms of diversity compared to those revealed in the literature, but they overlap to a large extent. For example, in the Huges et al. (2020) study, student teachers and teachers used a wide variety of tools such as projectors, tablets, clickers, cameras etc. in addition to the tools revealed in this study. And they also used ICT for a wide variety of purposes, providing alternatives to hard copies, model lifelong learning and model a new learning culture. It is thought that this situation arises from the teacher-centered approaches adopted by student teachers in the use of technology. As a matter of fact, some studies showed that the use of technology in the classroom was generally teacher-focused and transmissive. For example, in the study of Tondeur et al. (2012), most of the teachers used technological tools such as data projector or interactive whiteboard to deliver instruction. This is because of teachers' perceptions of technology use in classrooms. They see technology as a resource in their teaching activities rather than a tool that supports students' own learning (Voet & De Wever, 2017). Another factor is thought to be that in the classroom environments the participants want to focus primarily on their own teaching in order to survive, and therefore they employ mostly teacher-centered technology use.

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Examining A Long-Term Activity Process for The Field of Engineering Design Skills[1]

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Abstract

This research aims to examine the effects of a long-term activity regarding science, engineering, and design skills in primary school. The intervention design, one of the mixed method designs, was used in the research. The study group includes primary school 4th-grade students and two classroom teachers. There are 77 students in the quantitative phase of the research. At the qualitative stage, 12 students were included in the study by maximum variation sampling. As a data collection tool, the Word Association Test (WAT) was used in the quantitative phase, and student and teacher interview forms were used in the qualitative phase. In the analysis of the data, ANOVA and one-way MANOVA were used for repeated measurements in the quantitative part, and content analysis was used in the qualitative part. While the study's quantitative findings showed that the student's cognitive structures improved, the qualitative findings showed that difficulties, overcoming difficulties, and awareness codes gained intensity.

INTRODUCTION

The National Research Council (NRC, 1996) established a systematic and meaningful process incorporating applied activities within scientific research in science education. The field of science teaching is multifaceted and focuses on student experience, as emphasized by the NRC (2007). In this context, Science, Technology, Engineering, and Math (STEM) education has gained significance and popularity as a new approach. STEM education is an educational approach that includes four disciplines: science, technology, engineering, and mathematics (Altunel, 2018; Basham & Marina, 2013; Çepni & Ormancı, 2018). According to Jolly (2014), STEM is a movement that provides the scientific and mathematical development necessary for individuals to compete in the workforce in the 21st century. It has been found that the majority of methods in STEM education employ project-based, problem-based, design-based, inquiry-based, and the 5E learning models (Çepni, 2018; NRC, 2014). Çepni (2018) defined design-based learning as the engineering design process in which applications are made in the educational environment. English, King and Smeed (2017, p.256) described the stages of design-based learning: "determining the scope of the problem, understanding the boundaries of the problem, generating ideas, designing and constructing, evaluating the design, redesigning and structuring, and using interdisciplinary knowledge." NRC (2014) highlighted the connection between problem-based learning and STEM education as providing students with experience about the situations they may encounter. Çepni (2018) reported that STEM and project-based learning are similar, but STEM education includes project-based learning. Jolly (2014) emphasized that inquiry-based learning is essential for individuals to gain experience regarding science. Additionally, NRC (2012, p. 41) identified eight skills, focusing on the practices of scientists and engineers. These skills are: "asking questions, defining problems, developing and using models, planning and executing inquiries, analyzing and interpreting data, using mathematics, structuring explanations and designing solutions, evidence-based discussion, and communication." Based on these, in applying STEM in education and training, specific criteria have emerged. In this regard, Jolly (2014) expressed for STEM courses criteria: "courses should include real-world problems, engineering design processes, students in the practices, teamwork, meaningfully integrated of STEM disciplines." Similarly, according to Moore, Johnson, Peters-Burton, and Guzey (2016, p.5), the STEM learning environment should have the following: "meaningful learning, gaining experience, providing motivation, developing problem-solving skills, establishing interdisciplinary connections, engineering design, presenting real-world problems, integrating science and mathematics, project-based learning, and collaborative learning methods."

The following points were emphasized as results in relevant studies on STEM: its benefit to science education; the improvement of the design processes of the students (NRC, 2009), providing solutions to social problems (NRC, 2012); its inclusion of all kinds of structures and product designs that concern people (Tayal, 2013), development of engineering (Pruitt, 2014), implementing thinking skills a systematically data-driven (Kelly et al., 2017). Topalsan (2018) focused on developing teaching activities for the engineering design process and the problems in his study with prospective classroom teachers. In the study, it has been reported that pre-service teachers have problems defining and understanding the problem, finding a solution, and creating a model. Ecevit, Alagöz, Özkurt, and Köylü (2022) examined the activities in the 3rd and 4th-grade science textbooks. Researchers have stated that the activities are insufficient to provide students with scientific processes, thinking, and engineering skills. Karakaya and Yılmaz (2021) reported that the students can identify the problem, present the solutions, and make sense of the information they have acquired at an interdisciplinary level whose study with ninth-grade high school students within the scope of implementing engineering design processes. However, it has been reported that the participants could not reach the desired level in the design process. Syukri, Halim, Mohtar, Le, and Soewarno (2018) conducted a study on electricity and magnetism with secondary school students using a quasi-experimental design, integrating students' problem-solving skills with the engineering design process. The study stated that it benefited students to implement engineering design process applications in their courses. When the results of Kavak's (2019) study are examined, it is stated that STEM improves students' scientific process and problem-solving skills, and they successfully offer solutions to the problems they encounter. When the research findings of Yıldız and Ecevit (2022) are examined, it is seen that the participants develop themselves in cooperation and teamwork. The study conducted by Sun, Hu, Yang, Zhou, and Wang (2021) emphasized that students' attitudes toward STEM affect their critical thinking skills and that female students' attitudes toward STEM are more favorable than male students. Kavak (2019) reported that STEM activities provide students with more permanent and easy learning. Studies on this subject indicate that students' academic achievements increase, they display positive opinions, and their attitudes and motivations are also positively affected (Öztürk, 2020).

In this context, NRC (2009) referred to scientific knowledge and stated that the use of scientific knowledge contributes to the field of engineering design. Studies have reported that societies focusing on design-based science education and mathematics obtain and produce efficient information in technology (NRC, 2012). Regardingly, the Ministry of National Education (MNE, 2013) science curriculum emphasized scientific process skills and life skills. In addition, socioscientific issues, the nature of science, the relationship between science and technology, the social contribution of science, sustainable development, science, and career awareness were emphasized. In the progress, in addition to the scientific process and life skills, science-engineering and design skills were added to the MNE (2018) science curriculum. In the fourth grade of primary school, it is emphasized that product design, presentation, and end-of-school-year science festivals should be held in this field. However, these skills are not widely implemented across all educational levels despite their effectiveness. The relevant literature highlights that the least number of studies have been carried out with primary school (1st and 4th grades) and preschool students, while the largest sample group was at the secondary school and university level (Aydın et al., 2017; Hebebci, Usta, 2017; Christensen, Knezek, 2017; Kırılmazkaya, 2017; Karışan et al., 2019; Olszewski-Kubilius et al., 2017; Uğraş, 2019; Yıldırım, 2011). Accordingly, limited studies have been conducted at the primary school level, despite the positive results. However, considering the emphasis in the literature and the MNE science curriculum on engineering design skills, it is essential to develop applications and investigate the application process. In this sense, engineering design skills should be addressed in a process supported by scientific process skills and life skills based on scientific inquiry, including the criteria in a STEM-based teaching environment. From this point of view, the study aims to examine the results of using long-term activities to acquire engineering design skills in the primary school science curriculum. For this purpose, answers to the following questions were sought.

1. How do students make sense of their experiences during the activity process?
2. What is happening in the process?
3. How are students' cognitive structures affected?

METHOD

Research Design

Şimşek and Yıldırım (2016) describe the mixed method as research in which research problems are comprehensively discussed by using quantitative and qualitative methods together. The intervention design, one of the mixed methods, is defined as applying an intervention plan by examining the experiment for the persistent problem and supporting it with qualitative data. This study was conducted using the intervention design. In this design, qualitative data can be collected before, during, or after the experiment. Following the purpose of the research, a qualitative design was used during the experiment (Creswell, 2021; p.45). Thus, the effect of the applied process on the students was examined in depth. Accordingly, long-term activities were designed and implemented for primary school 4th-grade students. In this context, it is crucial in the research to interpret the quantitative results regarding the students' cognitive structures through a process. For this reason, it was tried to deeply understand the process by collecting qualitative data during the experiment. In this way, it is aimed to make sense of the quantitative data obtained regarding the learning process and to understand the effect of the activity process on the student.

Quantitative Stage

The basis of the quantitative phase of the research is the experimental design. Experimental design is expressed as a method in which the person conducting the study can decide, direct and test the variables in situations such as the process, content, and whom the study will be conducted with (Büyüköztürk et al., 2018). This study used quasi-experimental designs, as the random assignment of participants was impossible. However, the groups were determined as random. Accordingly, two groups were determined within the scope of the control group model and selected as the experimental and control groups. Control group students were not confronted with any material and application encountered by the experimental group in the process. The Word Association Test (WAT) was applied to two groups before, during, and after the experiment. In this context, repeated measurements were made for the dependent variable in both groups.

Table 1. The quantitative stage study pattern

Group	n	Pretest	Application	Post-test
Experimental Group	42	WAT	Long-term activities WAT	WAT
Control Group	35	WAT	Teacher–centered learning WAT	WAT

The problem situation subjects in the research were covered in the primary school third and fourth-grade curriculum. In this case, while the experimental group students were trained in science, engineering, and design skills within the scope of long-term activities, the control group received training without these activities. In this respect, the difference between the groups that received and did not receive this training was emphasized when interpreting the results. The control group was determined as this design is stronger than the single-group designs. As a result, we focused on the experimental group's experiences in the long-term activity. In this context, it is aimed to compare the changes in the cognitive structures of the students who participated and did not participate in the activities.

Study group

The research study group consists of 2 volunteer classroom teachers in the selected primary school and 77 students in total (42 students in the experimental group and 35 in the control group). The distribution of these students by gender is given in Table 2.

Table 2. Quantitative stage working group

Group	Gender	Frequency (N)	Percentage
Experiment	Girl	20	47.60
	Male	22	52.40
	Total	42	100
Control	Girl	16	45.70
	Male	19	54.30
	Total	35	100
Total	Girl	36	46.80
	Male	41	53.20
	Total	77	100

When Table 2 is examined, the distribution of the experimental group students by gender is 47.6% female (n=20), 52.4% male (n=22). The distribution of the control group by gender was 45.7% female (n=16), 54.3% male (n=19); a total of 46.8% female (n=36), 53.2% male (n=41). All students attend the fourth grade of primary school. These students are educated in a public primary school in the city center.

Experimental intervention process

In the study, activities were created in line with the STEM learning environment criteria, and these activities and their contents are presented in Table 3. As can be seen in Table 3, the study was formed in 6 steps: "presenting the scientific problem situation, structuring the scientific problem situation, scientific review, scientific resource research, use of scientific resources and product design"; activities and materials were designed for these stages. In the study, a real-world problem was first structured, and students were encouraged to develop projects. To this end, the poster named "TEKNOFAS" was designed by the researchers and asked, " How do you can carry today's plants into the future?" Within the scope of the question, students were invited to the project. A scientific article review was presented to the students within the scope of the "Life from Today to the Future" activity to better structure the students' problem situation. Then, with "Journey to the Colorful World of Plants," students' scientific resource review, with the experiment application named "I am observing my bean" about the students' scientific process skills. These stages were carried out with flipped learning. In the classroom, about essential concepts in the life cycle of flowering plants, students created a word cloud activity using the "WordArt" program, and the activity "Cut, Paste, Model and Tell" also modeled this process.

Table 3. Implementation process stages, activity contents, and timeline

Stage	Activity	Contents	Timeline
Presenting the Scientific Problem Statement	Teknofas: Invitation to the project with a poster	Do You Think We Can Bring the Date Tree 2000 Years Back Today? However, Can We Preserve Today's Plants for 1000 Years? Which part can we use to store the plant? What kind of environment can we design to store this part?	1-2 Weeks
Configuring the Scientific Problem Statement	"Life From Today To The Future"	"On the Way to Become a 2000-Years-Old Date Tree."	3.- 4. Week
Scientific Resource Review	"Journey to the Colorful World of Plants"	A source of scientific information on the life cycle of plants and flowering plants Word Cloud activity.	3.- 4. Week
Scientific Inquiry	"What happened to my beans?"	Experiment and observation of flowering plant life cycle "Cut, Paste, Model and Tell" activity	Week 5
Engineering Design Skill: Design	"Seed Banks?",	Designing seed banks with suitable simple materials	Week 6
Engineering Design Skill: Product	"I Design-I Produce"	Producing seed banks with suitable simple materials	7. Week

At these stages, it aimed for students to use scientific knowledge in their problem-oriented solution and design ideas. With the popular science article "Seed Banks?", students were encouraged to consider different design considerations for the engineering design process. After that, they developed different seed banks with the help of the simple materials given in the "I Design-Produce" activity and introduced them to each other in the classroom exhibition. These practices were applied to the students under the teacher's guidance during the periods determined by a booklet. In the application process, it was aimed that the students would recognize the parts of a flowering plant, recognize its life cycle, and in this way, design a product by understanding the conditions under which it should be stored for future use.

Data collection tools

The Word Association Test (WAT) was used within the scope of the quantitative research. It is stated that the Word Association Test (WAT) effectively measures individuals' knowledge and reveals their cognitive structures (Bahar, 2001; Bahar et al., 1999). Considering the study group of the research, it was deemed appropriate to choose WAT for students in terms of both significance and applicability. In this context, the key concept of "plant" was determined for activities based on science, engineering, and design skills. The pilot application of the prepared test was carried out by taking expert opinions. After the deficiencies and regulations were completed according to the results of the pilot implementation, the WAT was given its final form.

Analysis of data

The frequencies of the words associated with the key concepts by the WAT were determined for the quantitative data analysis. Therefore, directly and indirectly related concepts were evaluated as 1 point, unrelated concepts were evaluated as 0 points, and WAT scores were reached. Data distribution was performed for the word association test scores for the experimental and control groups, and descriptive statistics were examined for each measurement. Kolmogorov-Smirmov test and Q-Q plot findings were also examined, and it was decided that the pretest and intermediate test measurements of the experimental and control groups showed normal distribution. Descriptive statistics and Q-Q plot curves were considered in the post-test, and the distribution was close to normal. As the data was over 30, independence of observation and normal distribution assumptions were met, and the parametric tests were used. MANOVA results were preferred to compare groups in data analysis instead of independent samples t-test to avoid statistical errors and ensure appropriate data. Repeated measures ANOVA test was performed to compare the groups within themselves, and the results were evaluated accordingly.

Reliability and validity

The researcher first coded the answers of the experimental group students to WAT. In this process, the opinion of the relevant class teacher and also the expert opinion were taken. Then, the directly related concept, indirectly related concept, and unrelated concept status of the answers were revised. The related and indirectly related concept frequencies were used as the participants' WAT scores. Additionally, no mean score between raters was calculated. Based on this, it was considered that it did not need to calculate the fit index.

Qualitative Stage During Experiment

Working group

The interview was conducted by selecting one student from the teams of 3 and 4 people formed among the students in the experimental group through maximum variation sampling. According to Table 4, interview participants consisted of 48% female (n=5) and 52% male (n=7) students. The students were determined by considering their affective characteristics as criteria.

Table 4. Study group gender distributions

Group	Gender	Frequency (N)	Percentage
Experiment	Girl	5	48%
	Male	7	52%

Data collection tools

In the qualitative dimension, semi-structured interview forms were used for students and teachers. The semi-structured interview form was created in line with the interviewing principles. In this process, the stages of problem analysis, preparation of questions for problem analysis, and determination of the purpose of these questions were carried out. Expert opinions were obtained for the questions in this form, and arrangements were made regarding relevance and clarity for the purpose. Then, considering the student levels, interview forms were tried within the scope of pilot applications. Their final form was reached after correcting the missing or wrong parts of the interview questions. The forms were structured separately for each stage of the six-step implementation process.

Analysis of data

In qualitative data analysis, content analysis (Mayring, 2002) was done by transforming the students' answers into documents. In this process, first of all, all student responses were examined. Codes were developed from the answers given to the questions. In this direction, "difficulties, overcome difficulties, willingness to participate, positive emotion, impossibility, protection, preliminary preparation, self-awareness, teamwork, awareness" codes were created, and a coding rule was defined for each. A table has been formed with sample quotations related to these. Later, the code, definition, and related example table were developed and applied to all texts. In this way, the different stages of the student during the application process were examined using codes. Thus, student experiences are described with direct quotations obtained.

Reliability and validity

At the qualitative stage, the first coding was done for the interviews with the teachers and students. The answers for coding are listed as documents. Then, codes were created and defined by the researcher. The Code Definition, Related Examples table, developed in this way, was examined with another field expert, and a consensus was reached. The coding process was carried out on all data with quotations from the answers given for the later definitions. After the other expert rechecked the coding at the end of this stage, the analysis was completed as agreed.

FINDINGS

Findings Related to the Results of the Experimental Study

Within groups comparing

The repeated measurement ANOVA results of the data set obtained with the WAT measurements of the experimental group are presented in Table 5.

Table 5. Repeated measurement ANOVA results of the experimental group

Variable	Mean ($\bar{X}$)	Standard Deviation (SD)	N
Pretest	14.67	8.192	42
Midterm test	15.93	6.88	42
Final test	26.43	5.89	42

	df	Mean Squares	F	p	Partial Eta Square (η^2)
Cognitive Structure	1.767	1982.76	48.46	0.00	0.542
Error	72.427	40.916			

According to Table 5, it was found that there was a significant difference between at least two of the measurement results [F (2-82) = 48.46, $p < 0.05$]. Considering the repeated measurement results, the midterm and final test WAT's mean increased compared to the experimental group's pretest mean. In the post-test, it was concluded that the mean ($\bar{X}$ = 26.43) was the highest. Pairwise comparison findings regarding the significance of the differences between these measurement results are given in Table 6.

Table 6. Pairwise comparison of experimental group concept measures

(I) Concept	(J) Concept	Mean Differences	Std. Error	p	95% Confidence Interval	
					Lower Limit	Upper Limit
Final test	Pretest	11.762	1.371	0.00	8.34	15.184
	Midterm test	10.500	1.016	0.00	7.965	13.035

When Table 6 is examined, it is seen that there is a statistically significant difference between the third measurement and the first measurement ($p < 0.05$) and between the third measurement and the second measurement ($p < 0.05$). Accordingly, it was found that there was a significant increase in the students' word association test mean.

Repeated measurements ANOVA test results of WAT measurements of the control group at the same time interval are given in Table 7.

Table 7. Repeated measurement ANOVA results of the control group

Group	Variable	Mean ($\bar{X}$)	Standard Deviation (S)		N
Control Group	Pretest	14.06	6.32		35
	Midterm test	13.94	7.28		35
	Final test	14.89	6.58		35
	Df	Mean Squares	F	p	Partial Eta Square
Cognitive Structure	2	9.27	0.361	0.698	0.542
Error	68	25.66			

The Repeated Measurement ANOVA results were examined, and it was found that there was no statistically significant difference between the pretest, midterm test and final test WAT mean scores of the control group [$F(2-68) = 0.361$, $p > 0.05$]. When the means of the control group's measurements ($\bar{X} = 14.05$; $\bar{X} = 13.94$; $\bar{X} = 14.88$) are examined in repeated measurements, it is seen that the measurements are very close to each other.

Between groups comparing

The MANOVA results for examining the pretest, mid-test, and post-test averages of the experimental and control groups are given in Table 8.

Table 8. Descriptive statistics

	Teaching_Method	Mean ($\bar{X}$)	Standard deviation	N
Pretest	Control Group	14.06	6.32	35
	Experimental group	14.67	8.19	42
Midterm test	Control Group	13.94	7.28	35
	Experimental group	15.93	6.88	42
Final test	Control Group	14.89	6.58	35
	Experimental group	26.43	5.89	42

	Wilks' Lambda	F	Hypothesis df	p-value	Partial Eta Square
Teaching_Method	0.474	26.978	3.000	0.000	0.526

When the equality matrix of covariance matrices from the MANOVA results was investigated, it was observed that equality was achieved (Box's $M = 7.179$; $p = 0.334$). Wilks' Lambda results from the multivariate test result were considered in this direction. When Wilks' Lambda results were examined, it was determined that the teaching method variable differed significantly between the groups [F (df = 3) = 26.97; p<0.05]. While the mean scores of the experimental and control group students were closer to each other in the pretest and midterm test, it was determined that the mean of the experimental group ($\bar{x}$ = 26.46) in the final test was higher than that of the control group ($\bar{X}$ =14.89). The main effect results regarding the significance of the differences between these measures are given in Table 9. It was found that there were no significant differences between the groups' pretest (F (1) = 0.13; p = .72) and the midterm test (F (1) = 1.51; p = 0.22) results. When the post-test was examined (F (1) = 65.92; p = 0.00), it was revealed that there was a significant difference. As a result, according to the word association test findings of the experimental and control groups, there was no significant difference at the beginning between the experimental and control groups without any intervention. At the end of the intervention process, it was determined that there was a significant increase in the cognitive structure of the experimental group compared to the control group.

Table 9. Main effect results

Source	Independent variables	df	Mean Squares (K mean)	F	p	Partial Eta Square
Teaching Method	Pretest	1	7.09	0.13	0.72	0.00
	Midterm test	1	75.28	1.51	0.22	0.02
	Final test	1	2543.63	65.92	0.00	0.47

In this context, in the process carried out with STEM-based long-term activities, there are significant positive differences in the cognitive structure regarding target concepts.

Findings Related to the Results of the Qualitative Study

In presenting the scientific problem situation in line with the answers given by the students, "impossibility" and "protection" codes appear. The “impossibility” code includes quotes that express seeing the solution of the given problem as impossible. Quoting about it:

> *“The earth came to my mind. Then we cannot bring back the date tree 2000 years ago.”* (S1)

However, the code of “protection” means not allowing the code to be altered, carrying it into the future as it is, and keeping it intact. Quote for this:

> *“It reminds me that plants can be more for protection. For example, he says, can we bring the date tree 2000 years ago? For example, it seemed more like a protection thing to me. Then, when we protect the plants, they give us oxygen….”* (S12)

It has been determined that the codes of “difficulties, overcoming difficulties” occur at the stage of scientific inquiry and application of scientific resources review and product design. The difficulties code includes quotations expressing the situations that require manual dexterity in the activity process and the stages (observation, experiment, data recording) based on scientific inquiry. Quote for this:

> “*I had a hard time putting it in a sunny spot. Because our house does not get much sun*.” (S11)
> *“I have never been challenged anywhere. I just had a little trouble sticking it.”* (S10)

Product design includes quotations that express reasoning, analysis, creative thinking, cooperation, teamwork, getting support, reflecting terms, using the internet, researching, examining, gradual progress, being programmed, and drafting. Quoting about it:

> *"So first, we put the seeds squarely on the foil, one by one. Then we brought the pen. We divided it as plus (+). Then my friend said, "Can I do it too?" and I said OK. We did it together.*" (S8)
> *"I researched on the Internet how to design, how to make something for plants." (S10)*

At the scientific review stage, it was determined that "preliminary preparation" and "awareness" codes were formed. The preliminary preparation code includes quotes that express preparation before the event, creating a draft, working regularly, and being planned. Quote for this:

> *"We thought as a group, at home. Some of my friends had phone numbers. We thought a lot together. I even made one at home. To understand how it is done." (S5)*
> *"I had planned on paper. I had prepared a sketch. I followed that path."* (S4)

The code of "awareness" was used for observation, experimentation, data recording, and more. It includes expressions such as to sense, understand, and distinguish. Quote for this:

> *"I noticed my bean being a little brown and cracked."* (S7)

The codes of "positive emotion, willingness to participate, teamwork" are formed when presenting the scientific problem situation, scientific inquiry, scientific resource review, and product design (all steps). Positive emotion code includes quotes about the process experienced, expressing having a good time, having fun, and loving. Quoting about it:

> "*I am pleased. I felt happy. I enjoyed it"* (S9)
> *"I loved science very much. It is my favorite class so far. I loved the life cycle topics of these plants. I think it's fine now. But it will be better if it is increased over time."* (S5)

The request to "participate" code includes quotations that include the wishes of individuals during the activity and their demands for such activities. Quote for this:

> "*The project on the poster looks like an excellent project. I also looked and studied with my friends. It is a project to protect plants, and I am thrilled to participate in this project"* (S12)

The "teamwork" code includes team spirit, togetherness, making up for deficiencies, helping each other, mutual determination, and being productive. Quoting about it:

> *"Yes. I was able to work efficiently with my groupmates. I consulted with my friends. For example, how can we do it, how can we show it. I think it has been productive."* (S12)

It has been concluded that the codes of "protection, positive emotion, difficulties, overcoming difficulties, willingness to participate, preliminary preparation, self-awareness, teamwork" are formed in the product design step. It has been determined that the resulting codes occur at a higher rate in the product design phase than in other steps. Protection for this excerpt about the code:

> *"I understood how we can save the seeds. Then I realized what kind of place it is to preserve the seeds. It brought many things. My hand skills have improved, then we do many things at home. I also learned how to create a word cloud. It has been perfect for me, too."* (S7)

Excerpt about teamwork code:

> *"I was a little overwhelmed. I had a hard time doing it with aluminum foil. Then the people in my group told me how to do it. They told me how to wrap it. Then I learned how to do it too."* (S10)

Excerpt about the difficulties overcoming code:

> *"I did a little research. From the papers you gave me and a little bit of the internet. Let's say I tried to liken it to a seed bank."* (S12)
> *"With help from my friend, then took an inch of the middle strips. We used a ruler." (*S9)

Excerpt about preliminary preparation code:

> *"I had planned on paper. I had prepared a sketch. I followed that path." (*S4)

Excerpt about the willingness to participate code:

> *"You can improve more by doing more of these things. We can do more difficult things; it can be more comfortable. It may take longer." (*S6)
> *"I researched on the Internet how to design and make something for plants." (*S10)
> *"I think, we can do 2-3 or 5-10 more events. Because it is fun and beneficial." (*S8)

Quote about positive emotion code:

> "*I am pleased. I felt happy. I enjoyed it"* (S9)

However, the code of "self-awareness" includes quotes such as developing imagination and creativity, discovering one's talent, and turning to science. Quoting about it:

> *"Yes. Because here I understand the importance of group work. My hand dexterity is improving, and my imagination is expanding. It is also fun."* (S4)
> *"It allowed me to develop my sense of design. For example, nothing came to my mind before. As I thought and researched, I started finding more beautiful things and created my sketch. Afterward, I tried to reflect it together with the materials."* (S12)

In the interview with the teacher, it is seen that the codes of willingness to participate, positive emotion, and teamwork are formed when presenting a scientific problem situation, scientific examination, scientific resource review, and product design. Quote from willingness to participate:

> *"They were excited, they actively participated. They were curious."* (Teacher)

Quote for positive emotion code:

> *"It was a fun activity for children, and I believe it was beneficial."* (Teacher)

Excerpt about teamwork code:

> *"Students raised their friends as a group. They supported each other."* (Teacher)
> *"Their communication was good. They tried to improve the passive students and make up for their deficiencies."* (Teacher)

It has been concluded that the codes of "difficulties" and "overcoming difficulties" are included in the scientific review, use of scientific resources, and product design steps. Excerpt for the challenges code:

> "*While some of our students wanted to be meticulous, they were upset when they over-watered the plant, which rotted psychologically. In addition, because the class was so crowded, it was difficult to pay close attention to them during the experimentation process. Other than that, there was not much of a problem.*" (Teacher)

Excerpt from the code for difficulties overcoming:

> *"They thought repeatedly about the activities he was doing. They coped by trying to get support from their friends, teachers, parents."* (Teacher)
> "*The parents have been contacted. That way: the problem was solved.*" (Teacher)

When the qualitative findings were examined, it was concluded that the students and the classroom teacher had positive emotional and cognitive views on science, engineering, and design skills in long-term activities.

CONCLUSION, DISCUSSION AND SUGGESTIONS

The research was conducted with 42 fourth-grade students for seven weeks within the scope of long-term activities for applying science, engineering, and design skills. The results revealed that there was a significant positive difference in the cognitive structures of the students in the experimental group as indicated by the WAT scores [F(2-82) = 48.4, $p<0.05$]. However, there was no significant difference in the cognitive structures of the control group. Karışan and Yurdakul (2017) stated that these long-term activities positively affect the students in their studies in which plants and animals are included in the content, making observations, drawing graphics, and designing processes. On the other hand, in their study with secondary school students on socioscientific issues, which also includes 35 long-term activities, Öztürk, Altan and Tan (2020) stated that positive results have emerged in terms of cognitive, affective and design creation for students. In this respect, it is seen that the emergence of a significant difference in the results of the study coincides with the results in the literature. Experimental phase findings include long-term activities and course units within the scope of a science lesson, affecting students positively in terms of remembering concepts. In the applications made within the scope of this study, there are activities related to engineering design skills based on scientific inquiry. This context includes Web 2.0 applications, modeling activities, and scientific resource reviewing applications. The application process developed approximately the STEM learning environment (Jolly, 2014; Moore et al., 2016; NRC, 2012), which not only supports creating designs and products based on scientific knowledge about the problem but also supports concept learning.

The qualitative results have provided evidence for every research stage, a comprehensive comprehension of both student and teacher experiences. The coding that emerged at various points during the planned six-stage implementation procedure has reflected the diverse circumstances encountered in each stage. The codes "impossibility" and "protection" were revealed during the presentation of the scientific problem situation, while "difficulties" and "overcoming difficulties" were identified during the scientific review, use of scientific resources, and product design stages. The codes "positive emotion, teamwork, willingness to participate" were observed at all stages. The "awareness" code also occurred during the scientific review and inquiry stages. The highest occurrence of "preliminary preparation" codes was determined during the scientific inquiry and product design phases. These results were interpreted that although the beginning phase of a STEM-based application may present some difficulties, it can also lead to positive results in dealing with them. In different studies in the literature, there are findings that students cannot reach the desired level in some stages where difficulties are experienced for different stages of STEM activities processes (Karakaya & Yılmaz, 2021; Topalsan, 2018). The result showed that this process affects the students positively and that the practices can be done in primary school students. The code of awareness, which comes to the fore in scientific inquiry and product design stages, strengthens the idea of connecting the engineering design process with scientific inquiry. When teachers' views on science, engineering, and design skills are examined, it is concluded that they show a positive effect in line with the student's views. Accordingly, the finding reveals that students are affected positively regarding teamwork, cooperation, use of scientific process skills, communication, research, discovery, awareness of what they can do, holistic approach to events, collaboration, tolerance, working like a scientist, and efficient time use. Similarly, studies in the literature stated that implementing engineering design process applications in science teaching benefits students (Syukri et al., 2018).

The results obtained with the qualitative findings show that during the design and product development stage the students understood the scientific concepts related to the flowering plant's life cycle and associated it with the solution to the problem. The statements about the seed and its storage conditions are in the quotations. These findings support and explain the cognitive structure obtained at the quantitative stage.

In summary, when long-term activities are applied with appropriate tools and instructions at the primary school level, it positively affects students' cognitive structures in terms of remembering concepts and bringing together related ones. This process differs significantly from students who receive an education not supported by STEM-based long-term activities. This quantitative data is positively affected by the questioning learning environment reached with the qualitative findings and the awareness that emerges during the product design stages. Of course, it should not be overlooked that codes such as positive emotions, cooperation, and awareness, which are effective throughout the activity process, contribute to creating a positive learning atmosphere. The materials and instructions presented to the students in the research helped them overcome the difficulties they faced. The positive effects of communication and cooperation should be considered in long-term activities for students at this education level. Ecevit et al. (2022), finding that textbooks are limited in this regard, support the importance of preparing guide materials for teachers and students. The findings of this study provide evidence that it is possible to carry out STEM-based long-term activities for science engineering design skills in an inquiry teaching environment in primary schools.

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