JESEH

VOLUME
7
ISSUE
4

YEAR
2021

Journal of Education in

Science, Environment and Health

e-ISSN 2149-214X

JESEH
Journal of Education in Science, Environment and Health
Volume 7, Issue 4, 2021
e-ISSN:2149-214X

EDITORIAL BOARD

Journal of Education in Science, Environment and Health (JESEH)

The Journal of Education in Science, Environment and Health (JESEH) is a peer-reviewed and online free journal. The JESEH is published quarterly in January, April, July and October.The language of the journal is English only. As an open access journal, Journal of Education in Science, Environment and Health (JESEH) does not charge article submission or processing fees. JESEH is a non-profit journal and publication is completely free of charge.

The JESEH welcomes any research papers on education in science, environment and health using techniques from and applications in any technical knowledge domain: original theoretical works, literature reviews, research reports, social issues, psychological issues, curricula, learning environments, book reviews, and review articles. The articles should be original, unpublished, and not in consideration for publication elsewhere at the time of submission to the JESEH.

Abstracting/ Indexing

Journal of Education in Science, Environment and Health (JESEH) is indexed by following abstracting and indexing services: SOBIAD, Scientific Indexing Service (SIS), Education Resources Information Center (ERIC).

Submissions

All submissions should be in electronic (.Doc or .Docx) format. Submissions in PDF and other non-editable formats are not acceptable. Manuscripts can be submitted through the journal website. All manuscripts should use the latest APA style. The manuscript template for formatting is available on the journal website.

Contact Info

Journal of Education in Science, Environment and Health (JESEH)
Email: jesehoffice@gmail.com
Web : www.jeseh.net

JESEH
Journal of Education in Science, Environment and Health
Volume 7, Issue 4, 2021
e-ISSN:2149-214X

CONTENTS

Journal of Education in Science, Environment and Health
Volume 7, Issue 4, 2021 https://doi.org/10.21891/jeseh.962465

Understanding and Assessing STEM Teachers' Use of IBL to Address Achievement-Related Diversity: A Case Study from Turkey

Gokhan Kaya, Metin Sardag

Article Info

Article History

Published:
01 October 2021

Received:
02 January 2021

Accepted:
23 May 2021

Keywords

Inclusive education
STEM education
Inquiry based learning

Abstract

This study investigates how STEM teachers use inquiry-based learning (IBL) to address achievement-related diversity in their classroom practices. Data were collected from three teachers who participated in a long-term in-service teacher training program. Teachers' views were elicited through interviews, in-class observation, and evaluation forms. The data obtained were used in a narrative structure to create a detailed case study of each teacher and compare them. It has been determined that some strategies emphasize the diversity of success in IBL activities stand out more. Although these strategies are different, they enable IBL to progress in regularly and enable them to address the diversity of success in the classroom. The lack of a wide variety of strategies used by teachers can be seen as one of the crucial problems in case studies. In particular, the use of methods that will lead to better use of time in the classroom by using out of group work and evaluating them in terms of successful diversity may appear to be an improvement in terms of achieving the desired goals.

Introduction

Classroom contexts are complex and diverse in terms of students' educational and cultural backgrounds, accessible resources, school culture, structure and size of classes. These are some of the factors that lead to the emergence of diversity in classes and level differences between student achievements (Chin & Chia, 2006, Meijier, 2010). This complex and diverse nature of classes both requires proper management and teaching strategies as well as an effective learning process. These situations reveal the 'inclusive education approach.' Inclusive education aims to reduce the barriers to learning and participation for all students, not only for those with disabilities or who are classified as 'those with special educational needs' (Booth & Ainscow, 2002). It is essential to ensure that every child and young person has access to, participation and regular use of inclusive education (EC, 2015). This situation makes it imperative for teachers to recognize and use diversity in the classroom.

Diversity and inclusive education studies in the classroom have been carried out for many different purposes in the field for many years, and there has been a growing interest in diversity research in science and mathematics classrooms (e.g. Lan & de Oliveira, 2019; Nasir & Cobb, 2006; Ramnarain, 2019; Ryu, 2019). The classroom is a very complicated social and institutional place where one teacher endeavours to interact with lots of students, maybe 30-40, to support them. There is unavoidable heterogeneity in terms of talking and thinking (Mortimer et al., 2012) as well as achievement. For achievement, teachers must consider that students' starting points and academic levels are different (Booth & Ainscow, 2002, EC, 2015; Larina & Markina, 2019). It is also emphasized that responding to the students' needs by considering their different starting points is a generic competence that teachers should gain in contemporary teacher training programs (Gonzalez & Wagenaar, 2003; Starcic, 2010). It has been made clear that the interest comes from the growing diversity of classes in a globalizing world, and that the reports of the No Child Left Behind (U.S. Department of Education, 2002) and the European Commission on Progress towards Education and Training (2011, 2013 and 2015) are the responsibility of all education stakeholders, such as science and mathematics teachers.

Despite the reform movements in the field of science education to support equity and to try to close gaps in achievement, it is seen that there is a failure to reliably respond to the diversity of the student population (OECD, 2014). Programme for International Student Assessment (PISA) reports can be presented as evidence of this failure. For example, the PISA 2018 report (OECD, 2019) points out that a significant part of students, 24% of 15-year-old students in mathematics and 22% of the students in science, do not attain the necessary competence levels in these subjects in OECD countries. The EU commission's 2015 Education and Training Monitor showing that 22% of the 15-year-olds are underachievers in mathematics and 17% in science.

Inquiry-Based Learning (IBL) has positive effects on the acquisition of knowledge, conceptual understanding, and overcoming misconceptions and is thus a possible solution that can eliminate this adverse situation (Gormally et al., 2009). Additionally, according to Miles and Ainscow (2010), IBL practices are considered effective in addressing the diversity in classes. Brown (2017) also emphasized that IBL is a suitable approach to account for diverse student characteristics. The success and role of IBL in addressing diversity related to success have been emphasized in many studies. For example, Wilson et al. (2010) examined the effectiveness of inquiry-based materials and teaching and achievement gaps by various demographic variables such as gender, race/ethnicity, and socioeconomic status in terms of providing equitable opportunities to learn. Consequently, they point out that students can actively work on scientific problems based on their abilities and backgrounds in IBL classes. Therefore, the students will beneficially improve their skills and understanding compared to more prevalent science teaching. Additionally, it has been shown that it supports all students in terms of success. In the synthesis of IBL studies in Minner et al. (2010), the applications based on an inquiry led to a better understanding of scientific content regardless of students' ethnicity, gender and social-economic status, and 51% of the studies examined had a positive effect on students' science learning. Amaral et al. (2002) emphasize that IBL positively affects students' motivation and attitudes, while according to Gormally et al. (2009) it increases their self-esteem towards science lessons. In this way, IBL practices support all students whether they are at different levels or not, in terms of characteristics such as success, motivation, belief and attitude. Colburn (2000) places much responsibility for the success of IBL on the teacher, by emphasizing that teachers are the central decision-makers in terms how an inquiry approach is construed and adapted in the classroom. In another study, Larina and Markina (2019) categorized teachers' views on diversity and those who adopted the inclusive model sharply criticized the idea of dividing students into "strong" and "weak" groups within or between classes. From their point of view, such a classification renders the classroom's diversity inefficient for proper use. For them diversity and individuality are the principles of the inclusive model and are seen as models for educating everyone rather than excluding or stigmatizing "weak" students.

Successful use of IBL for diversity in classroom success is possible, with teachers successfully applying it in their classroom, as it emphasized the reports of the European Commission (EC, 2015). In this context, the Supporting Mathematics and Science Teachers in Addressing Diversity and Promoting Fundamental Values (MaSDiV) project that this study forms part of, is a study to develop modules for an inclusive science and mathematics education across Europe. The project was carried out using the IBL approach, which is often emphasized in the literature, to make the diversity of STEM teachers a positive part of science and mathematics lessons. According to the MaSDiV approach, inclusive mathematics and science education includes access for diverse learners in inquiry-based learning (IBL), using contexts to promote fundamental values and attention to diverse cultural backgrounds. Starting from this context, this study of IBL to support diversity in the classes of STEM teachers in Turkey attempts to understand how they use it. In this way, it will help us understand how inclusive mathematics and science teaching in schools are handled, used, and encountered by teachers. The research seeks answers to the questions are given below;

- How do lower secondary STEM teachers use IBL to address achievement-related diversity in Turkey?
- What do the teachers face the key challenges with and use as enabling strategies for effective classroom practices to address achievement-related diversity?

National Context and Diversity of Turkey

Subdivide text into unnumbered sections, using short, meaningful sub-headings. Please do not use numbered headings. Please limit heading use to three levels. Please use 12-point bold for first-level headings, 10-point bold for second-level headings, and 10-point italics for third -level headings with an initial capital letter for any proper nouns. Leave one blank line after each heading and two blank lines before each heading. (Exception: leave one line between consecutive headings.) Please margin all headings to the left.

Subdivide text into unnumbered sections, using short, meaningful sub-headings. Please do not use numbered headings. Please limit heading use to three levels. Please use 12-point bold for first-level headings, 10-point bold for second-level headings, and 10-point italics for third -level headings with an initial capital letter for any proper nouns. Leave one blank line after each heading and two blank lines before each heading. (Exception: leave one line between consecutive headings.) Please margin all headings to the left.

There are lots of factors of diversity in lower secondary schools in Turkey: language, religion, ethnic, achievement-related and ability diversity, which mean that students are gifted, and have cultural and socioeconomic diversity (ERG, 2018; TEDMEM, 2019; Eurydice, 2019). For example, OECD treats socioeconomic status in four parts namely the lower quarter, second quarter, third quarter, and an upper quarter in Turkey (Yıldırım et al., 2013). Besides, there are students at all level in mathematics and science literacy in 2015 (Taş et al., 2016). Additionally, the numbers of the ten main groups of foreigners who are not refugees residing in Turkey in 2018 are 104,444 (Iraq), 99,463 (Syria), 67,522 (Turkmenistan), 65,027 (Azerbaijani), 44,313 (Iran), 39,283 (Afghanistan), 36,507 (Russia), 34,727 (Uzbekistan), 25,784 (Egypt), 25,645 (Kirghizstan) (Republic of Turkey Ministry of Interior Directorate General of Migration Management, 2019).

Science teaching curricula for lower secondary schools have aspects for IBL for nearly the last 15 years in Turkey (MoNE, 2005; 2018). It is seen that every unit in the science curriculum contains acquisitions related to it. Besides, textbooks include lots of inquiry-based activities (Kaya & Yılmaz, 2016). However, these activities are mostly confirmation and structured inquiry activities. The curriculum structure is established so that students may bring their daily life experiences into classrooms and, conversely, can take their school experiences out. Research shows that teachers in the classroom cannot fully implement these ideas in the program (Tüysüz & Aydın, 2009). Although teachers are generally aware of the program's understanding and proposed activities, it is seen that this is not reflected in the classroom practices. The fact that the teachers do not have enough information about the new methods and their use in the application process, the inadequacy of the existing infrastructure (lack of equipment, crowd classes) are expressed as the reasons why the activities and understanding in the program cannot be fully implemented (Doğan, 2010). Science teachers are expected to improve students' reasoning skills and scientific thinking habits using socio-scientific issues in the new science curriculum (MoNE, 2018). Using contexts in IBL provides opportunity to teachers for accomplish to improve these skills.

Method

Research Model

The study was carried out using the case study design, which is one of the qualitative research approaches. Case studies involve an in-depth investigation of one or more than one case (Stake, 1995). Creswell (2009) describes a case study as an in-depth description of a case or multiple cases and its analysis. In the present study, IBL using STEM teachers to address achievement-related diversity was taken as the case. To conduct an in-depth analysis of this case, teachers' experiences and opinions were used. The whole participants' context handles within their settings as holistic case studies (Yin, 2009), and these compare as multiple case studies in this study. For that reason, the study was designed as a holistic multiple case design study. In this design, every participant is handled as a case in their own context, and then the cross-case analysis drawn on as a single unit of analysis (Yin, 2009).

Participants

All participants were members of an Erasmus+ project called MaSDiV, and the participant selection considered some criteria. These included joining all meetings, filling the evaluation form following the module homework, and obtaining in-class data (short clips, photos, students' worksheets). Besides that, the reinforcement contribution during the Continuous Professional Development (CPD) course is another selection criterion for the case studies. In line with these criteria, we investigate teachers' evaluation forms, classroom data, and face-to-face discussion in all CPD courses. At the end of this process, we chose nine teachers (5 science, 4 mathematics) from two different rural cities in Turkey. The researchers interviewed them using the semi-structured interview protocol. The protocol consists of three dimensions: teachers' knowledge and experiences concerning IBL, their understanding for the role and use of contexts in science and mathematics teaching, and their experiences through the CPD. After that, three of the teachers were selected for the national case study report for this paper. The efficiency of the interviews and class observations and the fact that they provided us with a thick description for creating the case study reports have been considered in this selection. The detailed descriptions about the participants are given below to fully understand the teachers' background, school settings, and relation to the project. Besides that, the given information could provide clarity of comparison of their cases. Classroom research in general and especially data recordings are especially of ethical character. This study follows the Turkish Research Council's most recent recommendations for scientific research and publication ethics regulations (2012) in collecting and handling data. All teachers and caregivers were informed about the right to terminate their participation at any phase of the research process without giving any reasons. Before the study, the teachers and parents were asked to sign the informed consent form to participate in the study. Concerning all ethical issues, a university IRB committee approved all data collection and analyzing processes.

Selma

Selma is a mathematics teacher and has eight years of teaching experience and has worked for one year in the school where she carried out implements our project studies. One of her essential goals is to educate responsible individuals who respect the fundamental values of society. Selma experienced inquiry-based learning, context, and cultural diversity in the CPD course firstly.

There are 37 teachers (five science, six mathematics) and nearly 600 students in the school. Each classroom includes between 30 and 35 students who are in a wide range of academic achievement diversity. For example, in the same class, some students have faced problems related to the four arithmetic operations, while some have good exam scores at the lower secondary school level. She also mentioned that parents have nearly same socioeconomic status, and they are not sufficiently concerned with the students' education properly. For this reason, she pointed out that the education of the student is limited to school only.

Bülent

He is a science teacher and has four years' teaching experience as well as has worked for two years in the school intervention was carried out. There are 69 teachers (ten science, ten mathematics) and nearly 1700 students. The students have been selected via academic average obtained at the primary school level to participate in the school. The teachers focus on national exam success in terms of academic achievement. Nearly 40 students at the school achieve high-level scores from the national college exam in every year. There are the diversities of socioeconomic, religion, academic and student past experiences in the school.

The teacher has some experiences with inquiry-based learning. These come from in-services training programs related to STEM education and problem-based learning. However, he first experienced the contexts for science and mathematics subjects and the relationship between them and IBL during CPD.

Ceren

Ceren is a science teacher who has three years of experience and has just started her professional career. Her current school where she began teaching is a village school. Since it is a village school, it has inadequate facilities in terms of existing materials and laboratory equipment. The school serves as a primary and secondary school, and there are 55 students at the secondary level. The total number of teachers is ten when primary and secondary schools are added together. Ceren is the only science teacher in the school.

When Ceren evaluates the student's potential in the school, the students' academic level and their motivation towards the courses are high. In terms of diversity in the school, cultural, economic, and success can be considered to be diversity. The students come to school from a few different villages, so this situation creates cultural diversity. At the same time, Ceren emphasizes that cultural diversity, which includes different mother tongues and arises due to students being from other regions of Turkey, is true for most students and teachers. This leads to teachers and students sometimes having difficulty in understanding each other. In terms of success, the success of the student in school varies greatly. The teacher attributes this situation to the constant teacher's change at the primary school level and emphasizes that it causes children's low reading skills. It is stated that students who change teachers too many times at the primary school level are weaker in reading skills, but students with less teacher exchange are better in this subject.

Ceren generally has contemporary views in terms of the inquiry-based learning approach. She sees the inquiry-based learning approach as "an approach that engages students to more thinking, allowing them to think and take the foundation of everyday life." Besides, under the teacher's guidance, it is emphasized that it is appropriate for students to conduct research and manage the process in a particular framework. She has some experiences that come from the undergraduate and postgraduate level related to IBL. She mentioned that she was educated to prepare IBL-based science lesson plans at the undergraduate level.

Data Sources

Multiple data sources were used in the study process (see Table 1). The interview transcriptions and classroom observations are the primary evidence to construct the case study report. Moreover, evaluation forms about classroom implementations of the teachers are drawn on as evidence.

Table 1. Data sources

Data sources	Focus	Details
Interviews (after the CPD)	Memories and reflection on their classroom implementation and experiences related to IBL and achievement-related diversity	124 min audio recordings
Video recordings (during the IBL lesson activities)	Indicator of teacher focus on diversity or facilities to draw on a diversity of the classroom	Five classroom hours audio-video recordings from the classroom.
Evaluation forms (related to class implementation)	These were used as a tool to self-reflection of teachers' implementation.	The forms were filled by teachers following their own IBL lessons.

We used three of them for each of the participants. Additionally, the Rope Activity, one of the MaSDiV project products (cf. MaSDiV, 2020) and Energy Resources and The Mars activities developed by teachers during teacher training, were used in the research. Energy Resources is an activity with a socio-scientific context in which the issue of whether the thermal power plants are installed or not is discussed, based on the positive and negative effects. The event was planned and implemented to research small groups. Students decide based on large and small group discussions from group interaction and individual thoughts based on research data. In the process, students make judgments by presenting arguments about whether power plants should be established considering their own culture and different cultures according to the positive and negative results of their establishment. Besides, the groups collect or develop arguments to support the view they advocate, generate ideas to raise social awareness (campaigns, symposia, etc.) and implement them. The Mars task is an IBL activity based on the research question: 'is there life in space?' In this activity, students work on the possibilities of living on Mars, how they could adapt to the presence of people on Earth if there were life, how to establish a social structure there and what could be the variables to consider. Through the activity, each group chooses a different research question and collects data about that question and tries to explain the context.

Data Analysis

The data obtained from different sources in the study were examined. The data analysis process consists of examining, coding, searching link of different sources. The whole process, as Merriam (1988) mentioned, is ongoing, recursive, and dynamic. In the first stage of data analysis, examining was done to reveal coding criteria for teachers' course records, interview records and other documents, in line with the purpose of the study and the diversity of the teacher's guidance. Then, coding was done using the criteria and by comparing these codings, it tried to identify common supporting structures in different sources. Finally, narrative case studies were created by bringing together analyses from different sources of data. Finally, by comparing case studies created independently of each other, common points about how IBL was used by teachers to support all students in the class and problems encountered were explained.

To ensure reliability and accountability, triangulation was attempted using multiple data sources (Patton, 1990). Also, classroom observations and interview transcripts were undertaken to increase accountability directly to presentations. Another essential concept is transferability (Yıldırım & Şimşek, 2016). To transfer qualitative study results in similar situations, the research process and findings have been explained in detail. The concept of consistency comes to the fore to make qualitative data reliable (Lincoln & Guba, 1986).

The qualitative data in this study were provided by the authors of this research observing the study group in pairs and reaching a conclusion by discussing and comparing the observation notes. As stated in the data analysis section, when the rater compliance ratios (77% and 75%) are taken into consideration, the data obtained are seen to be reliable. Finally, the confirmability of the data is another critical concept emphasized in qualitative studies (Erlandson et al., 1993). They use the quotations of the participants in explaining the qualitative data to minimize the researchers' prejudices and strengthen the findings.

Findings

In this section, case studies of three teachers and a comparison are given under separate headings. In this way, a general structure was attempted by explaining each teacher's case study in a narrative structure while cross-comparing them.

Selma

The Rope Activity was practiced in the lesson. The activity has four parts: a rope puzzle, four children, more rope puzzles, and design your rope puzzle. The teacher carried out the lesson in three phases. These phases are introduction, inquiry, and sharing of understanding. The teacher organized the class for group work, which were created as homogeneous in line with their achieving level, and explained the students' expectations for the introduction phase's implementation process. The teacher organized the activity settings for achievement diversity groups. The following quote is an example of teacher explanation in this stage. The quote [1] comes from classroom practice.

> I do not want to follow a specific solution, okay? Everyone will try to find an answer using different ways. You can use an equation, practice, and trial-and-error method. It is your choice. You must shape the answer to a question to take into consideration each idea in class. Okay?

After the initiation phase, the teacher and students studied activity in inquiry phases. The teacher supported the students to accomplish the investigation process and did not respond to the students' idea as true or false. The teacher tried to realize their mistakes and oriented low achievement students to alternative solutions ways to achieve. This situation shows parallelism with the teacher's initiation explanation (quote 1) and the following interview quote. The following quote is from the interview.

> Interviewer: Did you make anything to involve low achievement students in the activity process?
> Teacher: For example, I told them that they could predict rather than deal with addition extraction and equations. I told them they could virtually achieve something drawing. In this way, I guided them.

Lastly, all groups present their process and results in all classes in the sharing of understanding phases. The teacher encourages students to express their solution ways without judgment as true or false in this stage.

> "…now, it does not matter whether the answer to the first question is correct or not. I wonder only what you thought, okay? Let us start with the first group and tell us how you solved it. You can tell on the board." [Classroom observation]

The teacher faced some critical challenges in the inquiry stage. Classes are very crowded, and students' achievements are not high, and it is difficult to know how each student can learn more quickly in crowded classrooms. The teacher says the following:

> "I carried out this practice in groups, so high academic level students responded to questions, and low academic level students were more passive. Students' levels of understanding, their concerns and their abilities differ from each other due to individual differences. For example, someone can achieve it by music or drawing, so it is difficult to get involved in all of them. It is hard to learn how all of them understand more easily because the classes are very crowded."[Interview]

As mentioned above, the teacher tries to manage the process by providing alternative learning processes for low-achieving students. Instead of answering students' explanations as true or false, the teacher encourages students to engage in activity and provides them with the opportunity to choose a method for the solution of the problem.

Bülent

The teacher carried out the IBL activity related to whether there is life on Mars for the CPD course reflection. The activity implementation consisted of three main stages, which was pointed out that in his' lesson evaluation form. These are namely 1) introduction (setting up groups, giving the problem situation to students) 2) inquiry (reading and thinking about problem situation, studying in groups), and 3) sharing of understanding (making a poster (optional) or present the group's work) [Evaluation form].

While the teacher was carrying out the activity to address achievement diversity in the steps given above, he focused on the following three strategies.

(1) The teacher set up groups that are heterogeneous in terms of achievement. According to the teacher, this strategy has advantages. The teacher says in this situation that "… homogenous groups cause a problem. Because, if all members of a group have low academic achievement, we cannot conclude at the end of activity", and "… heterogeneous groups addressing academic diversity compete in an undesirable competition. For this reason, group pressure on the successful student is increasing." [Interview]
(2) The teacher endeavoured that each in the group has a voice.
(3) The teacher provided opportunities for students to do peer teaching within the group. In this process, the teacher constructed different discussion groups. They investigated data and discussed to confirm whether there is life on Mars [Evaluation form]. They prepared their written arguments collaboratively in the process. After that, each in the group presented part of their arguments. The teacher managed the process in this way. The following quote was from the classroom observations when the students presented group ideas based on arguments.

> "… Approximately 96% of the atmosphere is carbon dioxide, and the rest contains a small amount of argon, nitrogen and oxygen. There, thus, is not able to be life on Mars." [Classroom observation]

The teacher faced some critical challenges throughout the implementation. The first one comes from the achievement of diverse heterogeneous groups. High-achieving students became prominent and were made the leader in these groups. According to the teacher, if the classroom is not effectively managed, activity may not serve the purpose because the goal of the activity may not be available within a specific time. This problem comes from students not being familiar with group working. The teacher thinks that crucial challenges are to overcome with effective classroom management and that students adapt to the process. The following quote is from the interview for this situation.

> Interviewer: Which situations do you have difficulty in the activity process?
> Teacher: Classroom domination, time, and low cooperative study habits of students and time are a significant influence through the implementation process. It may not be sometimes possible that activity is carried out in 40 minutes. When students are given adequate knowledge, and if the classroom is managed effectively, it becomes useful. However, if there is a quarrel between two students, you have difficulties following the course plan or teaching.

Ceren

The general flow of the lesson is given to demonstrate how to use IBL when addressing achievement-related diversity. The teacher employed IBL activity related to renewable and non-renewable energy sources [Evaluation form]. The activity process consisted of three characteristic main stages. These are namely 1) introduction: Asking questions to get student attention and engage in the implementation process, 2) inquiry process: Students carry out an investigation and construct their argument, and 3) sharing of understanding.

Firstly, the teacher started the lesson by asking questions about the energy sources, which they learned for a few lessons to get the students' attention. For example, *What are the sources of electric energy? Which criteria are used to prefer renewable and non-renewable energy sources?* This section can be considered as the start of IBL. After this stage, the students were divided into heterogeneous groups considering their achieving level, carried out the inquiry process, constructed their argument, and persuaded each other in groups. The teacher paid attention to the heterogeneity of the groups and IBL to ensure diversity. She expresses this strategy, which she used in her answer to the interview questions.

> "Ensuring that the groups are heterogeneous was one of the factors that I have taken care of in achievement-related diversity. I created the groups randomly. So, each group had students who were successful, intermediate, and low."

In the inquiry process in order to support the diversity of success through the inquiry-based learning approach, the teacher "*trying to increase student participation*," "*each student contributing according to his / her level of development*" and "*each student's goals are not at the same level*" are indications that the teacher is successful in this sense. In particular, the teacher's response to the question about the contributions of IBL students supports this situation.

> "IBL leads to all students working together. For this purpose, I am already using high-achieving and low-achieving students for the inclusion of students at all levels (without actually making such a distinction). As long as all of the students are included in the process, perhaps not all of them achieved at the same level, but they all have an acquisition related to a topic. The size of this may be larger for some students and less for some students. Anyway, my expectations are not the same. I evaluate them according to their current capacity and level."

In the section of sharing the understanding, the students presented their views in mutual groups for about 20 minutes. Not only the teacher, but also the student took the teacher's role when she decided who accepts the following turn-taking is a remarkable class observation regarding students' participation. Ceren had previously done activities related to inquiry-based learning, and the in-class norm was established within the class, especially in the sharing of understanding section. The teacher does not participate in these interactions unless the students ask for the guidance of the teacher. The teacher takes the floor to summarize the general understanding and targeted scientific concept at the end of this section. The next class observation note explains this.

> "Students discuss the information they get in group discussions. Students present some arguments that will change their opinions in the course of the argumentation process. Some students in the group are more involved in the discussion. Nevertheless, even though some students participate more dynamically among the group, the group members allow each person to speak at least once; for example, one of the students has a warning to the other group member, 'Let Zeynep speak a little. Let talk'". [Classroom observation]

During the observation period, Zeynep was one of the students who never spoke. The group members give the right to speak to a student who has no words to say something or to a student who has difficulty expressing herself. Thus, students encourage other members of the group to contribute at all levels to show how diversity is supported in the classroom.

The most challenging point for the teacher and the students in the practices was the students' expectancy related to this work, whether they would be graded by the teacher. The students believe that they are always graded in different practices in the classroom other than lectures. At the same time, whether they are graded or not affects their motivation and fear of making mistakes. Also, the students found it challenging to decide what they would write in their reflective diaries or the arguments they would present in group work because they were not sure what the teacher's expectation is. Ceren describes this situation as follows:

> "Because the expectations of the children are always focused on a grade or score. I said that my expectation has just related to your participation regardless of any expected correct answer. I was mentioned that I wonder what you think about this course and what you learned, I added".

In terms of the main challenges in IBL, it is seen that the expectations of the education system in the Turkey are exam oriented. The teacher explains this situation as "*the system [The teacher tries to explain that the Turkish education system has many exams to pass secondary school to high school and as well as high school to university. Besides that, every secondary school grade level has a national exam in every semester] leads us to exam-oriented teaching. When students have such an expectation, this makes it difficult for us to make IBL applications*". In response to this situation and to meet the students' expectations, the teacher uses rubrics to solve these difficulties and thinks of it as a solution.

Comparison of Selma, Bülent and Ceren

First, even though the teachers carry out the lessons based on the same stages, there are some different strategies used by three teachers in the case study to address the diversity of success in their classrooms. Although these strategies differ, they show that teachers do not ignore the diversity of success in their classes. Consider these strategies in the context of inquiry-based learning.

At the outset, while three teachers use the inquiry-based learning approach, they consider the students' differences in achievement. In the interviews and class observations, it was noted that the teachers formed heterogeneous groups in general. Especially in Bülent and Ceren's classes, this situation is seen. At the same time, Bülent and Ceren emphasized why they preferred the heterogeneous group rather than the homogenous one. For example, according to Bülent, *"homogenous groups cause a problem. Because, if all members of a group are low in academic achievement, we cannot conclude at the end of activity"*. Selma also mentioned that a group work strategy was drawn on to accomplish the IBL activity. However, she said there was a problem related to the high and low academic students within group working. The trouble encountered by Selma is seen as a problem-related capacity of the class rather than homogeneity or heterogeneity of a group.

The teacher uses some strategies to support the low-level achievement student in different ways. On the one hand, Selma provides for students to determine the most convenient method for them. Besides that, she explicitly explains the new objectives to low-level students, and the teacher works with students as guidance. In this way, she addresses achievement-related diversity in the IBL methods, which explain the process. On the other hand, Ceren provides opportunities for students to do peer teaching and try to increase student participation. Bülent also endeavours to allow each student in the group a voice in the inquiry process. Furthermore, all of them guide the students to carry out an inquiry or to construct their argument. All the teachers have different problems in terms of critical challenges, such as not knowing the students' learning features, habits, expectations, crowded class, time, and exam-oriented teaching. The teachers try to overcome these challenges by effectively managing class, guiding, or using rubrics.

Conclusion and Discussion

As a result of interviews and in-class observations, it was determined that teachers used IBL by considering the diversity of success among students. In particular, it has been found that IBL is perceived and used as an approach that promotes student participation at all achievement levels. In parallel with this situation, it is considered that IBL both has a positive impact on knowledge acquisition, conceptual understanding and overcoming misconceptions (Gormally et al., 2009) and is a suitable approach to take into consideration diversity in classes (Brown, 2017; Miles &Ainscow, 2010). It is also emphasized in the research that the students who fail, especially in the class, are an element that has to support participation in the class (Rivet & Krajcik, 2004). The fact that teachers in the case study have different expectations from low and high-level students in IBL activities and the inclusion of all students in the group work are reflections of this situation.

It has been determined that some strategies to emphasize the diversity of success in IBL activities are prominent. Although these strategies are different, they enable inquiry-based learning to progress in the usual flow and enable them to address the diversity of success in the classroom. These strategies are presented in Figure 1. When Figure 1 is examined, it is seen that although the teachers have similar IBL processes, some use more of these strategies while others add different methods and try to engage all students. For the organization of heterogeneous groups in terms of the achieving levels for teamwork, although there are disagreements about how students should be organized in small group works, it is generally recommended to create heterogeneous ability in terms of their achieving level of the groups. It can be presented as evidence for teamwork in a heterogenous group that low-achieving students will be able to get assistance, encouragement, and stimulation from high-achieving students. In contrast, high-achieving students have a chance to enhance their cognitive abilities and presentation skills through interaction with low-achieving students (Cheng et al., 2008). A similar situation can be addressed in peer teaching. A meta-analysis study conducted by Lou et al. (1996) indicates parallel results: low-achieving students have a more effective process in heterogeneous than in homogeneous groups. In heterogeneous groups, although successful students seem to be more active, giving students the right to speak is one of the salient results. The teachers try to increase student's participation and allow that each in the group has a voice. For these situations, on the one hand, classroom dialogues contain interactive teaching and dialogic learning allows students to talk about some issues which affect their learning (EC, 2015).

On the other hand, Lack, Swars, and Meyers (2014) reported that academically low-performing students tend to avoid taking turns in interaction, taking a leadership role, and seeking explanations from their high performing peers in their study. Thus, the teacher's effective contribution in facilitating discourse provides opportunities for low-performing students to engage in discourse and contribute effectively for students with a low contribution (Empson, 2003). For this study, it can be said that the teachers' strategies in the IBL approach affect the formation of classroom norms and facilitate the students to engage in discourse.

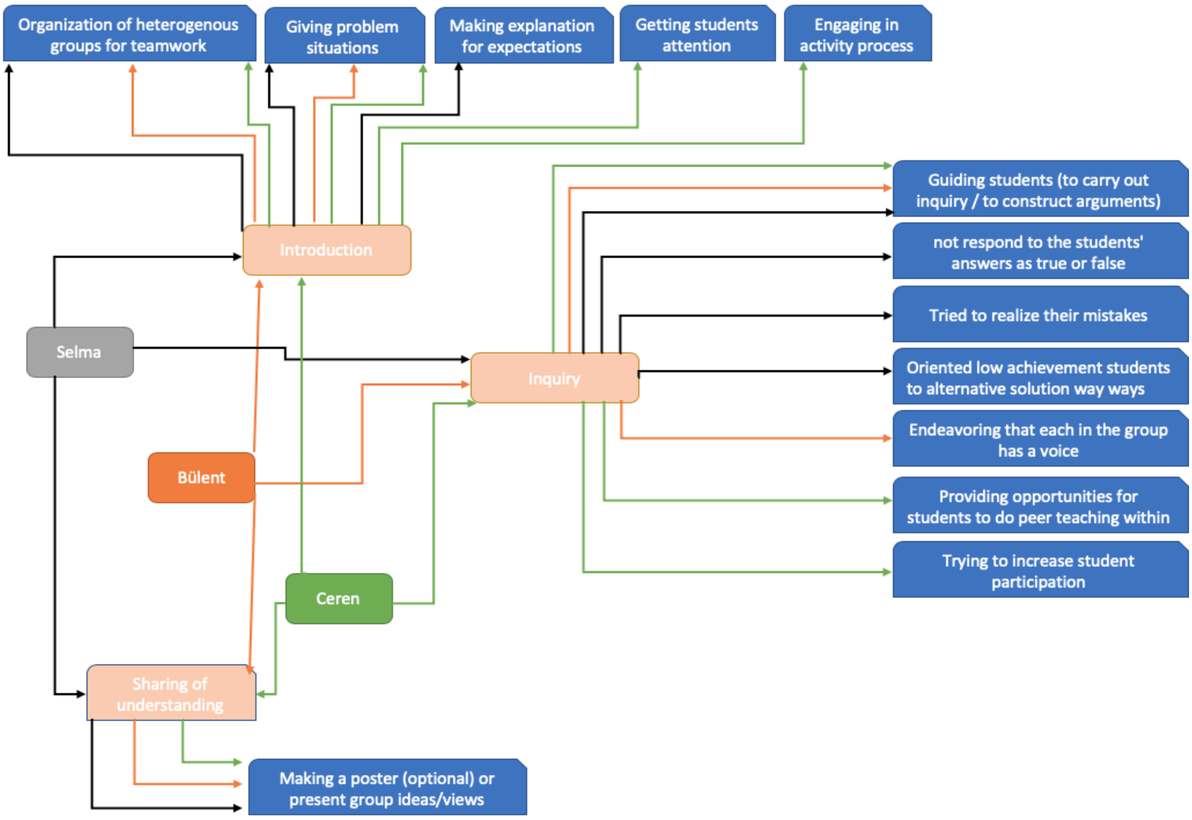


Figure 1. The general structure of IBL implementation of the teaches

Additionally, to support the diversity of success in the inquiry-based learning approach, the teachers try to increase student participation; this situation has parallels with other research results. Since research (e.g., Baxter, Woodward, & Olson, 2001; Lubienski, 2000) points out when a teacher does not try to facilitate the discussion of topic content (mathematics), low-performing students do not have nearly any opportunities to make fruitful contributions to the group. Therefore, it can be clearly said that the teachers give all students changes to engage in the process. All teachers guide the students, especially low achievement students, to carry out the inquiry or construct their argument. In this process, one teacher does not respond to the students' answers as true or false. This strategy shifts further interaction from triadic interaction (initiation-respond-evaluation) to chain interaction (initiation-respond-feedback…) (Mortimer & Scoot, 2003). In this way, students are enabled to interact with both the teacher and each other, and they have opportunities to realize their mistakes in the process. In the interaction, the teachers understand that the students cannot make inquiries; the teacher orients students to alternative solution ways, which are possible ways appropriate to the student's level. In other words, the teachers organize classroom activities for each student contributing according to their level of development. According to Lack et al. (2014), to affect student acquisitions positively, specifically assigning tasks related to the competence of low-performing students is one solution for low-status children. Therefore, it can be considered that the teachers are successful in terms of addressing achievement-related diversity in this sense.

The lack of a wide variety of strategies used by teachers can be seen as one of the crucial problems in case studies. In particular, the use of methods that will lead to better use of time in the classroom by using out of group work and evaluating it for successful diversity may appear to be an improvement in terms of achieving the desired goals. For instance, Meijier (2010) proposed that cooperative teaching, cooperative learning, collaborative problem-solving, heterogeneous grouping and alternative ways of learning approaches appear to be effective ways of dealing with diversity in school.

Unlike the other courses in terms of success in teachers' IBL activities, differentiation of expectations for each student or students at different levels may be considered concrete research evidence. This is achieved by conducting studies on similar IBL activities by determining how similar the most important one is from the student's current position. However, it is seen that the main problems are crowded classes and issues of the time. This situation shows itself as the most common problem in IBL activities. Besides, nationally-oriented, exam-oriented teaching has been seen as a situation that reduces teachers' use preferences, in particular with IBL.

Scientific Ethics Declaration

We, the authors, declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

Acknowledgements

The project MaSDiV received funding from the European Union Erasmus + Programme under grant agreement no. 582943-EPP-1-2016-2-DE-EPPKA3-PI-POLICY. This paper reflects only the authors' views and the European Union is not liable for any use that may be made of the information contained herein.

References

Amaral, O., Garrison, L., & Klentschy, M. (2002). Helping English learners increase achievement through inquiry-based science instruction. *Bilingual Research Journal, 26*(2), 213–239. https://doi.org/10.1080/15235882.2002.10668709.

Baxter, J., Woodward, J., & Olson, D. (2001). Effects of reform-based mathematics instruction on low achievers in five third-grade classrooms. *Elementary School Journal*, *101*(5), 529 –547. https://doi.org/10.1086/499686

Booth, T. & Ainscow, M. (2002). *Index for inclusion – developing learning and participation in schools.* CSIE. http://www.eenet.org.uk/resources/docs/Index%20English.pdf

Brown, J. C. (2017). A metasynthesis of the complementarity of culturally responsive and inquiry-based science education in K-12 settings: Implications for advancing equitable science teaching and learning. *Journal of Research in Science Teaching*, *54*(9), 1143-1173. https://doi.org/10.1002/tea.21401.

Cheng, R. W. Y., Lam, S. F., & Chan, J. C. Y. (2008). When high achievers and low achievers work in the same group: The roles of group heterogeneity and processes in project-based learning. *British Journal of Educational Psychology*, *78*(2), 205. https://doi.org/10.1348/000709907X218160.

Chin, C., & Chia, L. (2006). Problem-based learning: using ill-structured problems in biology project work. *Science & Education*, *90*(1), 44-67. https://doi.org/10.1002/sce.20097

Colburn, A. (2000). An inquiry primer. *Science Scope*, *23*(6), 42–44.

Creswell, J. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage.

Doğan, Y. (2010). Fen ve teknoloji dersi programının uygulanması sürecinde karşılaşılan sorunlar [The problems encountered during the implementation of science and technology curriculum]. Van *Yuzuncu Yil University Journal of Education, 7*(1), 86-106.

EC [European Commission, DG Education and Culture] (2011). *Progress towards the common European objectives in education and training, Indicators and benchmarks.* Brussels.

EC [European Commission, DG Education and Culture] (2015). *Education & Training 2020, Schools policy, A whole-school approach to tackling early school leaving.* Brussels.

EC [European Commission] (2013). *Investing in Children: Breaking the cycle of disadvantage*, *Recommendations*. Brussels.

Empson, S. B. (2003). Low-performing students and teaching fractions for understanding: An interactional analysis. *Journal for Research in Mathematics Education*, *34*(4), 305–343. https://doi.org/10.2307/30034786.

ERG (2018). *Eğitim izleme raporu 2017-18 [Education monitoring report 2017-18]*. http://www.egitimreformugirisimi.org/wp-content/uploads/2017/03/EIR_2017_2018_29.11.18.pdf

Erlandson, D. A., Harris, E. L., Skipper, B. L., & Allen, S. T. (1993). *Doing naturalistic inquiry: A guide to methods.* Sage.

Eurydice (2019). *Turkey overview*. Retrieved from: https://eacea.ec.europa.eu/national-policies/eurydice/content/turkey_en.

González, J., & Wagenaar, R. (Eds.). (2003). *Tuning educational structures in Europe*. University of Deusto.

Gormally, C., Brickman, P., Hallar, B., & Armstrong, N. (2009). Effects of inquiry-based learning on students' science literacy skills and confidence. *International Journal for the Scholarship of Teaching and Learning (3*)2, Article 16. https://doi.org/10.20429/ijsotl.2009.030216.

Hassard, J. & Dias, M. (2009). *The art of teaching science: Inquiry and innovation in middle school and high school.* Routledge

Kaya, G., & Yılmaz, S. (2016). The impact of open inquiry based learning on students' achievement and development of science process skills. *Hacettepe University Journal of Education*, *31*(2), 300-318. https://doi.org/10.16986/HUJE.2016016811.

Lack, B., Swars, S. L., & Meyers, B. (2014). Low- and high-achieving sixth-grade students' access to participation during mathematics discourse. *The Elementary School Journal*, *115*(1), 97-123. https://doi.org/10.1086/676947.

Lan, S.-W., & de Oliveira, L. C. (2019). English language learners’ participation in the discourse of a multilingual science classroom. *International Journal of Science Education*, *41*(9), 1246-1270. https://doi.org/10.1080/09500693.2019.1607618.

Larina, G. & Markina, V. (2019). Hidden mechanisms of differentiation: teachers’ beliefs about student diversity. *Journal for Mathematics Teacher Education*. https://doi.org/10.1007/s10857-019-09436-1.

Lincoln, Y. S. & Guba, E. (1986). Research, evaluation and policy analysis: heuristics and disciplined inquiry. *Review of Policy Research*, *5*(3), 546-565. https://doi.org/10.1111/j.1541-1338.1986.tb00429.x.

Lou, Y., Abrami, P. C., Spence, J. C., Poulsen, C., Chambers, B., & d’ Apolonia, S. (1996). Within-class grouping: A meta-analysis. *Review of Educational Research*, *66*, 423–458. https://doi.org/10.2307/1170650.

Lubienski, S. T. (2000). A clash of social class cultures? Students’ experiences in a discussion intensive seventh-grade mathematics classroom. *Elementary School Journal*, *100*(4), 377– 403. https://doi.org/10.1086/499647.

MaSDiV. (2020). Rope. https://icse.eu/international-projects/masdiv/

Meijer, C. J. (2010). Special needs education in Europe: inclusive policies and practices. *Journal of Inclusion*, *4*(2).

Miles, S., & Ainscow, M. (Eds.). (2010). *Responding to diversity in schools: An inquiry-based approach*. Routledge.

Ministry of National Education [MoNE]. (2005). *İlköğretim fen ve teknoloji dersi öğretim programı ve klavuzu [Elementary science and technology lesson curriculum and guide]*. Ministry of National Education

Ministry of National Education [MoNE]. (2018). *Fen bilimleri dersi öğretim programı [Science course curriculum]*. Ministry of National Education

Minner, D., Levy, A., & Century, J. (2010). Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching*, 47(4), 474–496. https://doi.org/10.1002/tea.20347.

Mortimer, E. F., Scott, P., & El-Hani, C. N. (2012). The heterogeneity of discourse in science classrooms: The conceptual profile approach. In *Second international handbook of science education* (pp. 231-246). Springer

Mortimer, E., & Scott, P. (2003). *Meaning-making in secondary science classrooms*. McGraw-Hill Education.

Nasir, N. S., & Cobb, P. (2006). Improving access to mathematics: diversity and equity in the classroom. *Multicultural Education Series: ERIC.*

OECD (2014). *TALIS 2013 results: an international perspective on teaching and learning*. OECD Publishing.

OECD (2019). *PISA 2018 results (Volume I): what students know and can do.* OECD Publishing. https://doi.org/10.1787/5f07c754-en.

Patton, M. Q. (1990). *Qualitative evaluation and research methods.*Sage.

Ramnarain, U. D. (2014). Teachers' perceptions of inquiry-based learning in urban, suburban, township and rural high schools: The context-specificity of science curriculum implementation in South Africa. *Teaching and Teacher Education*, *38*, 65-75. https://doi.org/10.1016/j.tate.2013.11.003.

Republic of Turkey Ministry of Interior Directorate General of Migration Management (2019). Residence Permits.

Rivet, A., & Krajcik, J. (2004). Achieving standards in urban systemic reform: An example of a sixth-grade project-based science curriculum. *Journal of Research in Science Teaching*, *41*(7), 669–692. https://doi.org/10.1002/tea.20021.

Ryu, M. (2019). Mixing languages for science learning and participation: an examination of Korean-English bilingual learners in an after-school science-learning programme. *International Journal of Science Education*, *41*(10), 1303-1323. https://doi.org/10.1080/09500693.2019.1605229.

Stake, R. E. (1995). *The art of case study research*. Sage.

Starcic, A. I. (2010). Educational technology for the inclusive classroom. *Turkish Online Journal of Educational Technology-TOJET*, *9*(3), 26-37.

Taş, U. E., Arıcı, Ö., Ozarkan, H. B., & Özgürlük, B. (2016). *PISA 2015 ulusal raporu [PISA 2015 national report]*. Ministry of National Education

TEDMEM. (2019). *2018 Eğitim değerlendirme raporu [2018 Educational Evaluation Report]*. Türk Eğitim Derneği Yayınları.

Tüysüz, C & Aydın, H. (2009). The elementary school science and technology teachers’ perceptions toward to new science and technology curriculum. *Journal of Gazi Educational Faculty Journal*, *29*(1) 37-54.

U.S. Department of Education. (2002). *No Child Left Behind Act of 2001.* U.S. Department of Education. https://www.ed.gov/offices/OESE/reference.

Wilson, C., Taylor, J., Kowalski, S. Carlson, J. (2010). The relative effects and equity of inquiry-based and commonplace science teaching on students' knowledge, reasoning, and argumentation. *Journal of Research in Science Teaching 47*(3), 276–301. https://doi.org/10.1002/tea.20329.

Yin, R. K. (2009). *Case study research: Design and method*. Sage.

Yıldırım, A. & Şimşek, H. (2016). *Sosyal bilimlerde nitel araştırma yöntemleri [Qualitative research method in social sciences]*. Seçkin Publishing

Yıldırım, H. H., Yıldırım, S., Yetişir, M. İ., & Ceylan, E. (2013). *PISA 2012 ulusal ön raporu [PISA 2012 national preliminary report]*. Ministry of National Education.

Author(s) Information

Gökhan Kaya
Kastamonu University
Faculty of Education, Kastamonu, Turkey
Contact e-mail: *gkaya@kastamonu.edu.tr*
ORCID iD: 0000-0003-4044-9243

Metin Şardağ
Van Yüzüncü Yıl University
Faculty of Education, Van, Turkey
ORCID iD: 0000-0003-2162-8289

Journal of Education in Science, Environment and Health
Volume 7, Issue 4, 2021
https://doi.org/10.21891/jeseh.987215

The Effect of STEM Activities on the Scientific Inquiry Skills of Pre-service Primary School Teachers

Elif Ozturk

Article Info

Article History

Published:
01 October 2021

Received:
05 January 2021

Accepted:
30 August 2021

Keywords

Primary school
Science education
STEM education
STEM activities
Scientific inquiry

Abstract

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

Introduction

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

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

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

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

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

Method

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

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

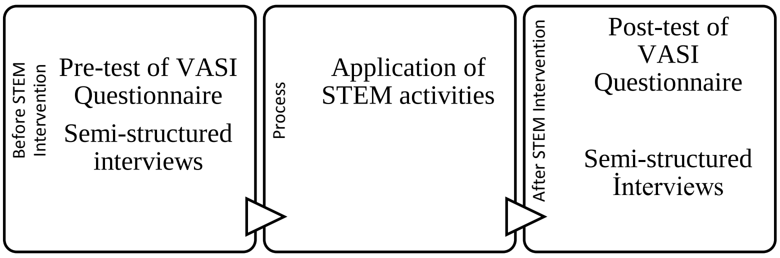


Figure 1. Research design of the study

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

Participants

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

Research Process

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

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

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

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

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

Figure 2. Sample products from the STEM activities

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

Table 1. Research Process

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

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

Data Collection and Analysis

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

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

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

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

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

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

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

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

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

Table 3. Semi-structured interview questions

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

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

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

Results

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

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

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

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

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

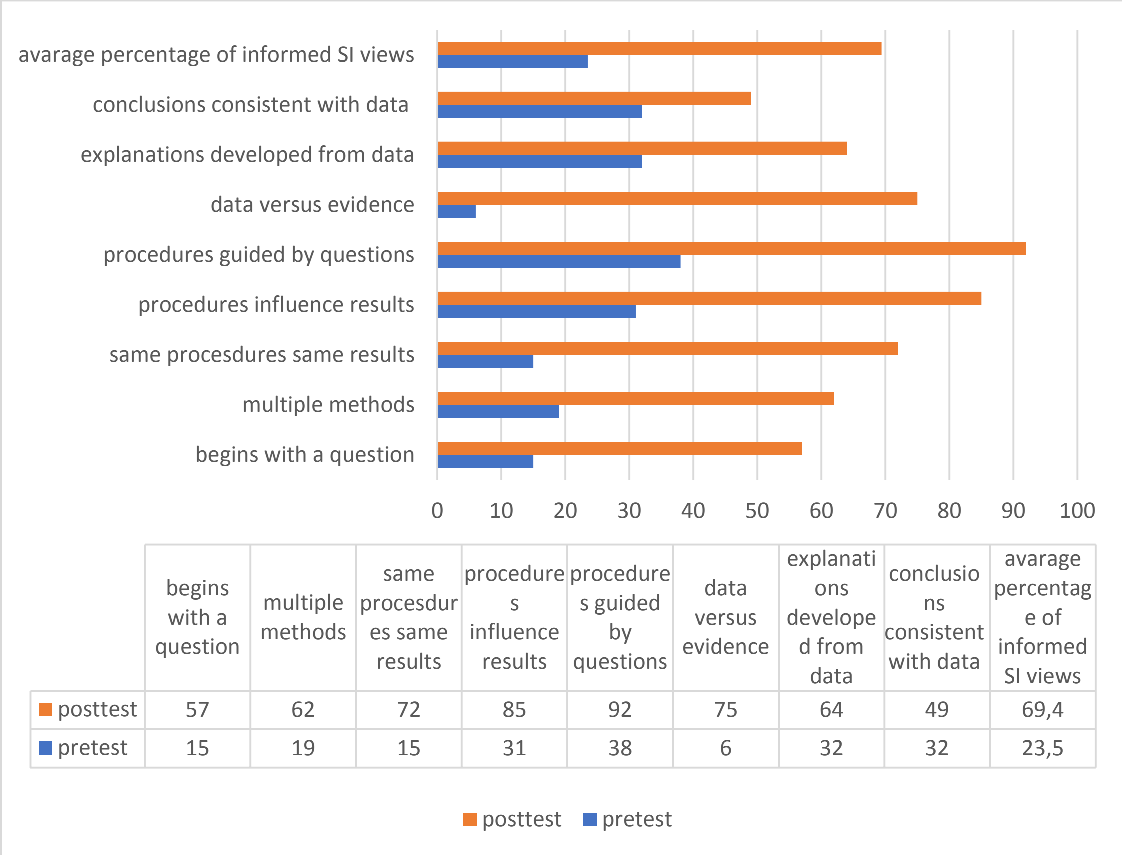
The Findings Related to the Effects of STEM Education on Preservice Primary School Teachers' Scientific Inquiry Skills

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

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

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

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



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

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

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

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

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

$p<.05$

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

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

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

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

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

Table 8. Exemplary quotations related to scientific inquiry

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

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

Conclusion and Discussion

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

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

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

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

Scientific Ethics Declaration

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

References

Abell, S. & Lederman, N. G. (2006). *Handbook of research on science education*. New Jersey: Lawrence Erlbaium Associates.

Ananiadou, K. & Claro, M. (2009). *21st century skills and competences for new millennium learners in OECD countries*. OECD Education Working Papers, No. 41, OECD Publishing. http://dx.doi.org/10.1787/218525261154

Anderson, R.D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education, 13* (1), 1-12. https://doi.org/10.1023/A:1015171124982

Aydeniz, M., Çakmakçı G., Çavaş B., Özdemir S., Akgündüz D., Çorlu S. & Öner T. (2015*). STEM Education Turkey Report "Today's Fashion or Necessity??"*. Aydın University, STEM Center, İstanbul. http://fs.hacettepe.edu.tr/hstem/dosyalar/STEMRaporu.pdf

Becker, K. & Park, K. (2011). Effects of integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A preliminary meta-analysis. *Journal of STEM Education: Innovations and Research*, *12*(5/6), 23 http://ojs.jstem.org/index.php?journal=JSTEM&page=article&op=view&path [] =1509

Bogdan, R. C. & Biklen, S. K. (2006). *Qualitative research in education: An introduction to theory and methods*. Allyn & Bacon. ISBN 978-0-205-51225-6.

Bybee, R. (2010a). A new challenge for science education leaders: Developing 21st century workforce skills. In *Science education leadership: Best practices for a new century,* ed. J. Rhoton, 33–49. Arlington, VA: NSTA Press.

Bybee, R. (2010b). *The teaching of science: 21st-century perspectives.* Arlington, VA: NSTA Press.

Bybee, R. W. (2010). What is STEM education? *Science, 329*, 996. http://dx.doi: 10.1126/science.1194998

Cavus-Gungoren S. & Ozturk E (2017). Assessing Preservice Science Teachers Views About Scientific Inquiry by Using Views About Scientific Inquiry (VASI) Questionnaire. *IX. International Congress of Educational Research*, Ordu, Turkey. p. 419-420.

Cavus-Gungoren, S. & Ozturk, E. (2021). What Do Pre-service Science Teachers Views about the Nature of Scientific Inquiry? *International Journal of Progressive Education, 17*(1), 421-438. http://dx.doi: 10.29329/ijpe.2020.329.27

Cresswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five traditions* (2nd ed.). California: Sage.

Çorlu, M. S., Capraro, R. M. & Capraro, M. M. (2014). Introducing STEM education: Implications for educating our teachers in the age of innovation. *Education and Science*, 39(171), 74-85.

DeCoito, I. & Richardson, T. (2018). *Beyond Angry Birds™: Using Web-Based Tools to Engage Learners and Promote Inquiry in STEM Learning*. In Information and Technology Literacy: Concepts, Methodologies, Tools, and Applications (pp. 410-433). IGI Global.

Frey, B. (2018). *The SAGE encyclopedia of educational research, measurement, and evaluation* (Vols. 1-4). Thousand Oaks, CA: SAGE Publications, http://dx.doi: 10.4135/9781506326139

Honey, M. Pearson G. & Schweingruber, H. (Eds.). (2014). *STEM Integration in K-12 Education, Status, Prospects, and an Agenda for Research*, Washington, DC: The National Academy Press.

Keeley, P. (2009). Elementary Science Education in the K-12 system. http://www.nsta.org/publications/news/story.aspx?id=5595

Lamb, S., Maire, Q. & Doecke, E. (2017). Key Skills for the 21st Century: an evidence-based review.https://education.nsw.gov.au/ourpriorities/innovate-for-the-future/education-for-a-changing-world/researchfindings/future-frontiers-analytical-report-key-skills-for-the-21st-century/KeySkills-for-the-21st-Century-Executive-Summary.pdf

Lederman, J. S, Lederman N. G., Bartos S. A., Bartels, S. L, Meyer A. A. & Schwartz R. (2014). Meaningful assessment of learners' understandings about scientific inquiry—the views about scientific inquiry (VASI) questionnaire. *Journal of Research in Science Teaching, 51*(1), 65-83. https://doi.org/10.1002/tea.21125

Lee, H., Kwon, H., Park, K., & Oh, H. (2014). Development and application of an integrated STEM education model based on scientific inquiry. *Journal of the Korean Society for Science Education, 34* (2), 63–78. https://doi.org/10.14697/JKASE.2014.34.2.0063

Leech, N. L. & Onwuegbuzie, A.J. (2009). A typology of mixed methods research designs. *Qual Quant* 43, 265–275. https://doi.org/10.1007/s11135-007-9105-3

Locke, E. (2009). Proposed model for a streamlined, cohesive, and optimized K-12 STEM curriculum with a focus on engineering. *Journal of Technology Studies, 35*(2), 23-35.

Merriam, S.B. (2013). *Qualitative Research: A Guide to Design and Implementation*. John Wiley & Sons Inc.

National Research Council (NRC), (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

National Research Council, (1996). *National science education standards* (Q183.3.A1N364 1996). Washington, DC: National Academy Press.

National Research Council, (2000). Inquiry and the national science education standards: A guide for teaching and learning. http://www.nap.edu

National Science Teachers Association [NSTA], (2000). NSTA Position Statement: Nature of Science.

National Science Teachers Association [NSTA], (2004). NSTA Position Statement: Scientific Inquiry.

National Science Teachers Association [NSTA], (2004). *Position statement on science teacher preparation*. Arlington, VA: National Science Teachers Association.

National Science Teachers Association [NSTA], (2006). NSTA position statement: Professional development in science education. http://www.nsta.org

Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Henriksson, H. W. & Hemmo, V. (2007). Science education now: A new pedagogy for the future of Europe. European Commission Directorate General for Research Information and Communication Unit. http://ec.europa.eu/research/science-society/ document_library/pdf_06/report-rocard-on-science-education_en.pdf

Sarı, U., Duygu, E., Şen, Ö.F., & Kırındı, T. (2020). The Effect of STEM Education on Scientific Process Skills and STEM Awareness in Simulation Based Inquiry Learning Environment. *Journal of Turkish Science Education, 17*(3), 387-405.

Schneider, R.M., Krajcik, J.S., Marx, R.W. & Soloway, E. (2002). Performance of students in project-based science classrooms on a national measure of science achievement. *Journal of Research in Science Teaching,* 39 (5), 410-422. https://doi.org/10.1002/tea.10029

Tai, R. H., Qi Liu, C., Maltese, A. V. & Fan, X. (2006). Planning early for careers in science. *Science*, 312, 1143-1145. https://doi.org/10.1126/science.1128690

Ültay, N. & Ültay, E. (2020). A comparative investigation of the views of preschool teachers and teacher candidates about STEM. Journal of Science Learning, 3(2), 67-78.

Ürey, M. & Çepni, S. (2014). Evaluation of the effect of science-based and interdisciplinary school garden program on students' attitudes towards science and technology lesson in terms of different variables. *Ondokuz Mayıs Üniversitesi Eğitim Fakültesi Dergisi*, *33*(2), 537-548. https://doi.org/10.19171/uuefd.37602

Wendell, K. B. (2008). *The theoretical and empirical basis for design-based science instruction for children.* Qualifying Paper, Tufts University.

Windschitl, M. 2009. Cultivating 21st century skills in science learners: How systems of teacher preparation and professional development will have to evolve. Presentation given at the National Academies of Science Workshop on 21st Century Skills, Washington, DC.

Yamak, H., Bulut, N. & Dündar, S. (2014). The effect of STEM activities on 5th grade students' science process skills and attitudes towards science. *Gazi Eğitim Fakültesi Dergisi*, *34*(2), 249-265. https://doi.org/10.17152/gefd.15192

Yıldırım, A. & Şimşek, H. (2008). *Sosyal Bilimlerde Nitel Araştırma Yöntemleri* (in Eng: Qualitative Research Methods in Social Sciences) (6. Baskı). Seçkin Yayıncılık.

Author Information

Elif Öztürk
Giresun University
Giresun University Faculty of Education Güre Campus
28200 Giresun, Turkey
Contact e-mail: elif.ozturk@giresun.edu.tr
ORCID iD: 0000-0002-3764-4526

Journal of Education in Science, Environment and Health
Volume 7, Issue 4, 2021 https://doi.org/10.21891/jeseh.961060

The Effect of Engineering Design Based Science Teaching on Decision Making, Scientific Creativity and Design Skills of Classroom Teacher Candidates

Elcin Ayaz, Rabia Sarikaya

Article Info

Article History

Published:
01 October 2021

Received:
04 January 2021

Accepted:
23 June 2021

Keywords

Engineering design-based
Decision-making skill
Scientific creativity

Abstract

This study aims to examine the effects of engineering design-based science teaching (EDBST) on classroom teacher candidates' decision-making skills, scientific creativity and engineering design-based process skills. The random design of the quantitative approach with a pretest-posttest control group was used in the study. The study group consists of 60 teacher candidates convenient sampling method and studying at the Faculty of Education Department of Classroom Education of a state university in Ankara in the 2017-2018 academic year. The implementations of the study continued in the Science and Technology Laboratory Applications-II course for 14 weeks in accordance with the content integration of STEM. Study data were calculated through dependent and independent groups t-test, one-way repeated measures ANOVA and multivariate variance analysis (MANOVA). When the results of the study were examined, it was seen that the skills of the classroom teacher candidates, where the courses were taught with engineering design-based science teaching, developed positively.

Introduction

Countries can enable the required workforce by providing innovation based on technological developments. Innovation is the process of enhancing science and technology to provide economic and social benefits. Innovative thinking is important in terms of knowledge generation. Innovative thinking has been discussed since the 2000s, particularly in the USA which significantly, affects the world education system. STEM derived as an educational term in 2001 by Judith A. Ramaley, the director of the National Science Foundation, has become widespread since this date and the engineering process has started to be included in the inquiry-based science education (Schwartz et al., 2007). STEM consists of the abbreviations of the first letters of the words "Science, Technology, Engineering and Mathematics. In recent years, many countries have started to include STEM education, where the engineering process is effective in their curricula to comply with global world standards. The engineering process in education provides meaningful learning by establishing a connection between STEM disciplines with knowledge learned and knowledge experienced in the real world (Çorlu & Çalli, 2017, p.11-14). Real-world problems are addressed in engineering design-based learning processes, which have become widespread in the world. In K-12 education, students are asked to produce solutions to the problems encountered in the real world by benefitting from the engineering understanding (Brophy et al., 2008). In the engineering process in education, disciplines such as science, technology and mathematics are used to produce solutions for problems (Çorlu & Çallı, 2017, p.11-14). The content of the disciplines, such as science and mathematics, which are among the basic sciences, is combined with the content of technology and engineering disciplines. As a result, the concept of "integrated STEM" emerges. In integrated STEM, the important point is not to consider the knowledge and skills in the fields of science, mathematics, technology and engineering separately; on the contrary, to create 'knowledge-based ideas' that connect these four fields to each other (National Academy of Engineering [NAE] and National Research Council [NRC], 2009). In this context, disciplines need to be integrated into the concept of STEM (Aslan-Tutak et al., 2017).

In the literature, although there are various approaches where STEM disciplines are integrated into the education process, three approaches are frequently mentioned. These are multidisciplinary, interdisciplinary and transdisciplinary approaches (Hacıoğlu, 2017). In the multidisciplinary approach, other disciplines are included in an organized way in line with a theme. The information belonging to each discipline is combined around a common theme determined by learning separately (Drake & Burns, 2004). In the interdisciplinary approach, information related to the subject is learned from two or more disciplines, and the barriers of these disciplines are overcome and integrated to gain depth in line with the common objective (Vasquez et al., 2013). In the transdisciplinary approach, a process in which researchers from different disciplines are active to obtain information while investigating a common problem is maintained (Tress et al., 2007). Similarly, the transdisciplinary approach is based on the integration of disciplines on real-world problems (Vasquez et al., 2013). Furthermore, STEM education can be integrated into courses based on content and context. In content integration, multiple STEM content areas are combined in one curriculum with an aim to accomplish big ideas. In context integration, STEM disciplines are used when solving a context-related problem (Moore et al., 2014).

Today, individuals need to have life skills appropriate for the digital age (Resnick, 2002). Developed countries replan their educational processes in order not to fall behind the fast-growing scientific and technological developments. In this process, it is highly important to update curricula (Kaptan & Kuşakçı, 2002; Karahan et al., 2015). In Turkey, there have also been radical changes in science education in the last 30 years (Batı, 2014). In 2013, certain changes were made in the science curriculum and the 4+4+4 education system was put into effect. The objective of this program is to raise well-educated science, literate individuals. Knowledge, Skill, Perception and Science Technology Society Environment (STSE) learning and sub-learning domains were added to the 2013 science curriculum. In the STSE learning domain, there are sub-learning domains such as socio-scientific subjects, sustainable development, social contribution of science, science-career consciousness, nature of science and science and technology relationship (Ministry of National Education [MoNE], 2013). As well as scientific process skills and life skills, engineering design skills were added to the updated science curriculum in 2018. In this way, learners will be ensured to think innovatively, solve problems by integrating STEM disciplines, create products and add value to them (MoNE, 2018).

Thanks to the updated science curriculum, students can gain life skills (such as decision-making, creative thinking, analytical thinking, entrepreneurship, team skill and communication problem-solving) and use them correctly. They are expected to find alternative solutions to the problems they encounter in daily life, be creative while doing this and decide on the most appropriate solution among the available solutions. When the studies conducted on STEM education in our country are examined, it is seen that these are mostly the studies carried out with classroom teacher candidates studying at the department of science teaching or secondary school students (Bozkurt, 2014; Ercan, 2014; Altan et al., 2016; Yıldırım, 2016). In the international literature, it is emphasized that STEM activities need to be included in the K-12 education system and the importance of the use of design-based education especially at primary school level is mentioned (Kolodner et al., 2003; Rogers & Postmore, 2004; Wendell & Rogers, 2013; Adams, 2015; Brown et al., 2016). It is observed that the studies conducted related to design-based practices at the primary school level are insufficient in our country. The lack of long-term studies aimed at practice significantly attracts attention (Acar, 2018; Genek, 2018; Altaş, 2018; Koçak, 2019; Yavuz, 2019). The aim of this study is to investigate the effect of engineering design-based science teaching on decision-making skills, scientific creativities and engineering design-based process skills of classroom teacher candidates. Within the scope of this research, the engineering design-based science teaching (EDBST) was performed with the STEM activities prepared in accordance with content integration.

Engineering design-based science teaching is a teaching approach that uses engineering design and scientific research processes together to enable students to acquire targeted behaviors, to produce alternative solutions to daily life problems, to decide on the most appropriate solution, and to integrate all STEM disciplines (Wendell, 2008). Engineering design-based science teaching should not be understood as transforming science courses into engineering courses. What is important here is the integration of these two areas (Gencer, 2017). The designs made should be used as a tool for generating solutions against scientific knowledge and real life problems (Fortus, et al., (2004). In other words, engineering design-based science teaching is a common combination of scientific research and engineering design. In an engineering design-based science education, designs include problems students may encounter in daily life. It is important for students to choose the most appropriate solution among the solutions for these problems in terms of understanding that a problem has more than one solution. It also contributes to the development of higher-order thinking skills of students such as creativity, critical thinking and problem solving (Wendell, 2008). Engineering design based science teaching; It aims to integrate the fields of science, technology, engineering and mathematics, to enable students to work by bringing together different disciplines like an engineer, and to come up with a product by finding creative solutions to problems (Bybee, 2010).

In this study, engineering design process steps were used in the experimental group. The process in question starts with the determination of the problem, the possible solutions are searched and the most suitable solution is selected according to the characteristics of the problem, a prototype for the solution is made and tested, if it does not work, it is revised or rebuilt. While the course was taught with the classroom teacher candidates in the control group in line with the 5E learning model, the EDBST embedded in the 5E learning model was applied to the classroom teacher candidates in the experimental group. This study is important in terms of putting forward the activity examples suitable for science and engineering learning outcomes in the science curriculum and guiding classroom teacher candidates who will be the implementers of the curriculum regarding the engineering design-based process.

The main problem statement of this research is "what is the effect of engineering design-based science teaching on decision-making, scientific creativity and engineering design-based process skills of classroom teacher candidates?”

The problems and sub-problems proposed in compliance with the purpose of the research are listed below:

1. Does the engineering design-based science teaching (EDBST) process affect the decision-making skills of classroom teacher candidates?

   1.1) Is there a significant difference between the pre-process decision-making skill mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?
   1.2) Is there a significant difference between the post-process decision-making skill mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?
   1.3) Is there a significant difference between the pre-process and post-process decision-making skill mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model?
   1.4) Is there a significant difference between the pre-process and post-process decision-making skill mean scores of the classroom teacher candidates in the control group to whom the courses were taught with the 5E learning model?

2) Does the engineering design-based science teaching (EDBST) process affect the scientific creativity of classroom teacher candidates?

   2.1) Is there a significant difference between the pre-process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?
   2.2) Is there a significant difference between the post-process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?
   2.3) Is there a significant difference between the scientific creativity sub-dimensions posttest mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?
   2.4) Is there a significant difference between the pre-teaching and post-teaching process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model?
   2.5) Is there a significant difference between the pre-teaching and post-teaching process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the 5E learning model?

3) How do the engineering design-based process skills mean scores of the classroom teacher candidates change at the end of the EDBST embedded in the 5E learning model where six different designs were made?

   3.1) Is there a significant difference between the engineering design-based process skill mean scores of the classroom teacher candidates at the end of EDBST embedded in the 5E learning model where six different designs were made?

Method

Research Model

In this study, a quantitative process approach was followed and the random design with pretest-posttest experimental and control groups, which is one of the semi-experimental designs in which the effect of the independent variable on the dependent variable was examined, was used. The experimental and control groups were randomly assigned from ready groups (Büyüköztürk et al., 2012). While the course was taught with the classroom teacher candidates in the control group according to the 5E learning model, the process of EDBST embedded in the 5E learning model was applied to the classroom teacher candidates in the experimental group. Before and after the process, the decision-making skill test and scientific creativity skill test were applied to the classroom teacher candidates in the experimental and control groups. Furthermore, the teacher candidates were evaluated through the engineering design process form that they filled out every week throughout the study. The information regarding the implementation process of the study is shown in Table 1.

Table 1.Implementation process of the study

Group	Pretest	Procedure	Posttest
Control Group (Classroom Teacher Candidates)	Decision-Making Skill Test Scientific Creativity Test	5E Learning Model	Decision-Making Skill Test Scientific Creativity Test
Experimental Group (Classroom Teacher Candidates)	Decision-Making Skill Test Scientific Creativity Test	5E Learning Model + STEM Education (Engineering Design-Based Science Teaching)	Decision-Making Skill Test Scientific Creativity Test

Population and Sample of the Research

The pilot study of the research was carried out with the teacher candidates studying in the fourth grade in the department of classroom teaching of a state university in Ankara in the 2017-2018 fall semester. Pilot studies, where eight volunteer teacher candidates participated as two males and six females, continued for six weeks.The universe of the main study is made is composed of three branches which of the classroom teaching department of the university where the pilot study is made; the sampling of the study, is composed of two branches determined by an random assignment from the universe. As pretest, Decision-Making Skill Test (DMST) was applied to three classes of the second grades of the department of classroom teaching, and as a result of the analyses performed, it was observed that the decision-making skill mean scores of the classes were close to *each other. The general mean scores of DMST were found as Class A* $\bar{X}$*=17.11; Class B* $\bar{X}$=16.07; Class C $\bar{X}$*=17.9*, respectively. In the random assignment performed within the groups, the class 2-A was determined as the control group and the class 2-B as the experimental group. As in the experimental group, the courses were taught with engineering design-based science teaching in class 2-C. The course contents were arranged in line with the expert feedbacks received from this course and used in other classes. The courses were taught in accordance with the engineering design-based science teaching embedded in the 5E learning model in the class 2-B, which is the experimental group, and according to the 5E model in the class 2-A, which is the control group.

According to the DMST pretest scores of 27 teacher candidates in the experimental group, they were heterogeneously divided into six groups as Group 1 (4 individuals), Group 2 (5), Group 3 (5), Group 4 (4), Group 5 (4) and Group 6 (4). Table 2 shows the distribution of the study sample by gender.

Table 2. Distribution of the sample by gender

	Female	Male
Control Group	27	6
Experimental Group	25	2
Total	52	8

Data Collection Tools

Decision-Making Skill Test

The Decision-Making Skill Test (DMST), which was developed by Ercan and Bozkurt (2014) for the students at the secondary school level, is one of the data collection tools used in the quantitative data collection process of this study. This test was reorganized by Bozkurt (2014) in compliance with the classroom teacher candidates, and validity and reliability studies were conducted. The items in the test consist of the questions that include giving answers by paying attention to the multiple criteria in certain characteristics to be measured.

The mean difficulty of the test, which consists of 11 items that have only one correct answer for each question, is 0.52. Moreover, there are three difficult, three easy, and five medium difficulty questions in the test. The internal consistency coefficient of the test rearranged for the teacher candidates is 0.71. The KR-20 reliability coefficient of the test applied to third-grade teacher candidates was calculated as 0.59 in the study. It can be stated that DMST is moderately reliable since its reliability coefficient is between 0.50 and 0.80 (Salvucci, Walter, Conley, Fink, & Saba, 1997). An example question of a decision-making skill test is given below:

The following information will be needed to solve questions 1, 2 and 3. Serkan's father, Yakup Bey, who is a student at a primary school in Sinop district center, is planning to open stationery. He determined 6 place options for him to open the stationery and listed them as follows.

Yakup Bey, together with his son Serkan, prepared some criteria determining the importance of the options in order to decide on one of the 6 options and transferred them to the table below.

Criteria / Options	Place A	Place B	Place C	Place D	Place E	Place F
Competition Conditions	8	6	8	8	4	7
Proximity to the Center	4	9	7	3	6	6
Finding a School Nearby	6	7	6	5	6	7
Store Rents	6	4	7	6	5	7
Finding a suitable width shop	4	3	4	4	3	6

The score application related to the criteria given in the table was made over 10 points.

1. The high-scoring option for one criterion is the most suitable for opening stationery, the lower-scoring option less suitable. For example, for the shop rents criterion, 10 points indicate that the rent is very suitable, 1 point indicates that the rent is not suitable. First of all, it pays attention to the conditions of competition and then the other criteria. Which location option would be most appropriate for Mr. Yakup, who included it in the evaluation?

A) Place A B) Place B C) Place C D) Place D E) Place E F) Place F

2. Serkan, who thinks that the criteria of renting a shop and having a school nearby are more important than other criteria for their decision, which place option would be most appropriate for Serkan to suggest to his father?

A) Place A B) Place B C) Place C D) Place D E) Place E F) Place F

3. When scores between 1-4 are unsuccessful, scores between 5-7 are acceptable, and scores between 8-10 are considered to be very successful in the scoring performed on the criteria, it is most appropriate for Mr. Yakup and Serkan, considering all the criteria, to choose which place for stationery?

A) Place A B) Place B C) Place C D) Place D E) Place E F) Place F

Scientific Creativity Test

Scientific Creativity Test (SCT) was developed by Hu and Adey (2002) in accordance with the scientific creativity model. In this model, there are three main dimensions; a) process (dreaming, thinking), b) traits (fluency, flexibility, originality), and c) product (incentive product, science, science phenomenon, science problem). SCT, which was adapted into Turkish by Kadayıfçı (2008), was applied to 64 students in the 9th grade. As a result of the factor analysis performed to test the construct validity, it was determined that the factor loads of the items were higher than 0.30 and the reliability coefficient of the test was 0.73. In this study, Cronbach's alpha reliability coefficient of SCT applied to the participants was calculated as 0.89. In the test, there are seven open-ended questions. The first question is the unusual uses; the second one is discovering the problem, the third one is developing the product, the fourth one is determining the scientific imagination, the fifth one is solving the problem, the sixth one is applying science experiments. The seventh one is designing the product.

The first question of the scientific creativity test is given below:

1. Write down the possible scientific uses of a piece of glass

The answers to this question were analyzed according to the three main dimensions of the model. The scoring of the question is as follows: 1 point for each answer given (fluency), +1 point (flexibility) for each different application. For each answer seen in less than 5% people, +2 points (for 5-10%) +1 point (originality) is given.

Weekly Engineering Design Process Form

The classroom teacher candidates were asked to complete the design task assigned to them every week in accordance with the EDBST process. In this design process, the teacher candidates used the Engineering Design Process Form developed by the researchers. In accordance with the engineering design process, teacher candidates primarily produced individual solutions for daily life problems based on the learning outcomes determined regarding the learning area. Afterward, all ideas were placed in the decision-making matrix where the criteria and limitations of the problem were included, and the most suitable solution was chosen by the group. After this phase, the teacher candidates performed the prototype drawing. Then, the product was prepared by using the materials to obtain the product. After the preparation, the product was tested and presented. Throughout the process, a total of 36 (thirty-six) designs were produced in the experimental group as 6 (six) designs from each group. In the evaluation of the engineering design process of each group, the engineering design process evaluation rubric (Challenge Rubric) used in engineering education in NASA (2015) Glenn Research Center (GRC) and adapted into Turkish by Uzel (2019) was used. The engineering design process consisting of 8 (eight) stages according to this rubric was evaluated based on three levels (1: Below the targeted level, 2: At the targeted level, 3: Above the targeted level).

Implementation Process

In the pilot study of this research, eight voluntary fourth-grade classroom, teacher candidates were enabled to produce designs in accordance with the primary school fourth-grade science learning outcomes. Before the pilot study, the participants were informed regarding the STEM education process by the researcher. The implementations were performed in the science laboratory at extracurricular hours determined according to the participants. The researcher and the instructor of the course planned 14-week course plans and design processes that were necessary for the main study by benefiting from this pilot study process and literature. Adjustments were made regarding the course plans and design processes by obtaining the opinions of three experts.

In this study, the teacher candidates who participated in the main study took the “Science and Technology Laboratory Applications-I” Course in the fall semester before the study. In this course, Primary School third grade science gains were carried out in the 5E learning model. Therefore, it is thought that teacher candidates have sufficient knowledge about the 5E learning model. At the beginning of the main study, all of the second-grade students were comprehensively informed about the engineering design process. The need for this approach in the education system and its importance in terms of the future of the country were explained to the participants. The students in the experimental group carried out an innovation activity in order to better understand this process that they would perform. In the innovation activity, the students were asked to revise and develop the equipment found in the school in the next 10 (ten) years. Then, they were enabled to draw a prototype. The 3D (Sketch-Up) drawing program was introduced to benefit from the technology while drawing the prototype.

The main study was carried out in the "Science and Technology Laboratory Applications-II" course with the second-grade classroom teacher candidates studying at a public university in Ankara in the spring semester of the 2017-2018 academic year. The courses were taught in accordance with the 5E learning model in the control group and the engineering design-based process embedded in the 5E learning model in the experimental group. In both groups, the courses were conducted by the same researcher and the same subjects were covered. Differently, the engineering design-based process was applied in the experimental group. At the beginning of the implementation, six heterogeneous groups were created from the teacher candidates in the experimental group. In the deepening phase of the 5E learning model, the groups were given daily life problems related to learning outcomes and asked to find solutions by using the engineering design process. In this context, the teacher candidates completed six different design tasks in 14 weeks. In Figure 1, the pictures of the implementation process of the teacher candidates in the experimental groups and their designs can be seen.

Figure 1: Computer use, design process and drawings

One of the applications in the experimental and control group is the Simple Electrical Circuits in the Lighting and Sound Technologies unit. This subject was studied in the control group according to the 5E model, following the introduction, exploration, explanation, deepening and evaluation stages. In the entrance step, students' prior information was checked, their attention was drawn and their motivation for the lesson was provided. During the exploration phase, students were given simple electrical circuit elements to establish circuits and discover faults in the circuit. In the explanation phase, the concepts were first explained to the students and then explained by the teacher. During the deepening phase, the subject was associated with daily life. In this way, students adapt their knowledge and problem solving approach to new events and problems. In the evaluation phase, the process of realizing the educational activities of the students was evaluated by the teacher in all dimensions.

The subject of Simple Electric Circuits was studied in accordance with the engineering design process embedded in the 5E model in the experimental group. In the experimental group, the lessons were taught as in the control group until the deepening stage. During the deepening phase, the following problems related to Simple Electrical Circuits were given to the students.

- "To design lighting tools that can easily make and manage for a few days to meet the lighting needs of the residents in their homes, if electricity cannot be supplied to houses and workplaces due to a major transformer failure in the city."
- "To design a low-cost lighting device that can draw water from the well in the evenings when there is no light in the garden in a small residential area where water is drawn from a well to houses with a barrel where there is no city water, that can produce electrical energy while drawing the water from the well and thus illuminate the inside and surrounding of the well."
- "It will enable us to locate our easily lost vehicles such as keys and remote controls we use in daily life; To design a vehicle with a lighting system mounted on the vehicle, connected to a mobile phone or tablet, to be managed with a coding system."
- "To design a vehicle to be managed with a coding system, connected with a mobile phone or tablet, with a lighting system mounted on the object that will enable us to locate small items lost in bags."

The students chose one of the above problems as a group and made their designs using the circuit elements. The students started the process by determining the problem, determined possible solution suggestions and chose the most suitable solution among these solutions according to the characteristics of the problem. Later, they drew a prototype for the solution, turned it into a product and presented the product by testing. If the product does not work, they revised it or made it again. The evaluation phase of 5E was done with the measurement tools related to the subject in both the experimental and the control groups.

Data Analysis

In this study, descriptive and predictive statistical analyses were performed. The decision-making skill and scientific creativity mean scores of the teacher candidates in the experimental and control groups before and after the engineering design-based science teaching were calculated and compared with the independent and dependent groups t-test. During the analyses, Cohen's d effect size was calculated for t-test in case that the difference between the groups or variables was significant. For the effect size, Cohen's d values were defined as small, medium and large, respectively as 0.20 (small), 0.50 (medium) and 0.80 (large) (Cohen, 1988; Rosenthal, & Rosnow, 1991). The pretest and posttest mean scores in the fluency, flexibility and originality dimensions, which were the sub-dimensions of scientific creativity, were compared with one-factor MANOVA. Furthermore, the data obtained from the engineering design process forms of the teacher candidates, in the experimental group were rated according to the engineering design process evaluation rubric and the repeated measures were compared by using ANOVA. In the statistics related to parametric tests, the assumptions of normal distribution of the populations and homogeneity of the population variances need to be ensured (Gravetter, 2013). In this study, these criteria were examined in the statistics performed. It was observed that the groups showed normal distribution in the independent group's t-test and the results of the Levene's test revealed a value of $p>0.05$, the equality of the variances was not broken. When the normality assumptions of the test were examined in the dependent group's t-test, it was assumed that the groups showed normal distribution. It is seen that the distribution is normal, and the assumptions of the sphericity test are fulfilled by testing the assumptions of the repeated measures ANOVA. In the one-way MANOVA analysis, it is seen that one-way extreme values and multivariate normality are ensured and the premises of Levene's test are homogeneous.

Validity and Reliability

In data collection and data analysis processes, validity and reliability studies are very important in the interpretation of the data accurately. In quantitative researches, validity is to measure the characteristics that the test aims to measure by separating from other characteristics. Internal validity is the level of explaining the changes observed in the dependent variable with the independent variable. In a research, it is necessary to pay attention to factors that threaten internal validity such as the selection of study group, maturation of the individuals involved in this group for the study, history of the participants, loss effect of the participants, tools used for data collection, pretest effect and interaction effect of the groups (Büyüköztürk et al., 2012). In addition, the consistency of the data is highly essential. In this study, these factors were considered. The classroom teacher candidates were randomly assigned from three classes. The courses in each class were taught according to the 5E learning model appropriate for the same course contents. The duration necessary for the maturation of the study group was taken into consideration. Data collection tools were applied after ensuring validity and reliability. It was paid attention to that the groups were not in interaction with each other. The instructor of the course attended courses with the researcher in all classes. The 14-week period between the pretest and posttest is sufficient for the participants not to remember the pretest.

Principles for Ensuring Reliability

In quantitative researches, reliability is defined as the measuring degree of what is aimed to be measured by the measurement tool, the correct understanding of the characteristics to be measured and the degree of interpretation (Christensen, JohsNson, & Lisa, 2015). The necessary statistical tests were performed for the "Decision-Making Skill Test" and "Scientific Creativity Test" used in the study and reliability coefficients were obtained. It was decided that these tools were reliable measurement tools for the study group.

Findings and Interpretation

In this study, the effect of the Engineering Design-Based Science Teaching (EDBST) on decision-making skills, scientific creativities and design skills of classroom teacher candidates was examined. The findings related to the problem and sub-problems of the study are as follows:

1. Does the engineering design-based science teaching (EDBST) process affect the decision-making skills of classroom teacher candidates?

The mean scores that the classroom teacher candidates in the experimental and control groups received from the Decision-Making Skill Scale were taken into consideration to determine whether the EDBST process affected the decision-making skills of the teacher candidates.

Teacher candidates receive one (1) for each correct answer and zero (0) for each wrong answer in this 11-item test.

1.1. Is there a significant difference between the pre-process decision-making skill mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?

Independent t-tests were provided to compare the pre-teaching decision averages of classroom teacher candidates who were taught with the MTTFÖ embedded in the 5E learning model and the classroom teacher candidates who taught the courses with only the 5E learning model.

Table 3. Pre-process decision-making skill mean scores of the classroom teacher candidates

Decision-Making	*N*	$\bar{X}$	*sd*	*t*	*p*
Control	33	0.5187	0.20	-1.576	0.120
Experimental	27	0.5955	0.16		

p>0.05

When Table 3 is examined, it is seen that the difference between the pretest mean scores is not statistically significant [$t(58) = -1.57$, $p>0.05$]. This result reveals that the students in the experimental and control groups are equal in terms of pre-processing decision-making skills.

1.2. Is there a significant difference between the post-process decision-making skill mean scores of the classroom teacher candidates teachers to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?

Independent t-tests were provided to compare the post-teaching decision averages of classroom teacher candidates who were taught with the MTTFÖ embedded in the 5E learning model and the classroom teacher candidates who taught the courses with only the 5E learning model.

Table 4. Post-process decision-making skill mean scores of the classroom teacher candidates

Decision-Making	*N*	$\bar{X}$	*sd*	*t*	*p*
Control	33	0.5730	0.19	-3.261	0.002*
Experimental	27	0.7172	0.12		

**p<0.05, **p<0.01*

When Table 4 is examined, it is seen that the difference is in favor of the experimental group statistically [$t(58) = -3.21$, $p<0.05$]. The effect size of the difference between the posttest means scores of the experimental and control group was calculated as *Cohen's d: 0.84.* Since this value is in the range of 0.2<d0.8, it is accepted as a large effect, according to Cohen (1988). According to this result, it can be interpreted the EDBST process increased the decision-making skills of the teacher candidates in the experimental group at a higher level compared to the control group.

1.3. Is there a significant difference between the pre-process and post-process decision-making skill mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model?

Dependent t-test, whose assumptions were ensured, was performed to compare the decision-making skill mean scores of the classroom teacher candidates in the experimental group before and after the EDBST embedded in the 5E learning model and the results are given in Table 5.

Table 5. Pre-test and post-test mean scores related to decision-making skills of the experimental group

Decision-Making	*N*	$\bar{X}$	*sd*	*t*	*p*
Pretest	33	0.5955	0.16	-3.525	0.002*
Posttest	27	0.7172	0.12		

**p<0.05, **p<0.01*

When Table 5 is examined, it is seen that, after the EDBST process, the decision-making skill posttest mean scores of the teacher candidates in the experimental group are higher than their pretest mean scores and the difference between the mean scores is statistically significant [$t(26) = -3.52$, $p<0.05$]. The effect size of the difference between pretest and posttest mean scores was calculated as *Cohen's d: 0.68*. This value is accepted as a moderate effect according to Cohen (1988). According to this result, it can be interpreted that the EDBST process increased the decision-making skills of the teacher candidates in the experimental group at a high level.

1.4. Is there a significant difference between the pre-process and post-process decision-making skill mean scores of the classroom teacher candidates in the control group to whom the courses were taught with the 5E learning model?

Dependent t-test, whose assumptions were ensured, was performed to compare the decision-making skill pretest and posttest mean scores of the teacher candidates in the control group to whom the courses were taught with the 5E learning model and the results are given in Table 6.

Table 6. *Decision-making pre-test and post-test mean scores of the control group*

Decision-Making	*N*	$\bar{X}$	*sd*	*t*	*p*
Pretest	33	0.5187	0.20	-1.943	0.061
Posttest	27	0.5730	0.19		

p>0.05

When Table 6 is examined, it is seen that the decision-making pretest and posttest mean scores of the teacher candidates in the control group to whom the courses were taught with the 5E learning model are close to each other and the difference is not statistically significant [$t(32) = -1.94$, $p>0.05$].

2. Does the engineering design-based science teaching (EDBST) process affect the scientific creativity of the classroom teacher candidates?

To determine whether the EDBST embedded in the 5E learning model affected the scientific creativity of the classroom teacher candidates, the scores that the teacher candidates in the experimental and control groups received from the Scientific Creativity Test were statistically compared.

2.1. Is there a significant difference between the pre-process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?

The scientific creativity means scores of the classroom teacher candidates in the control and experimental groups before the EDBST embedded in the 5E learning model were compared with the independent samples t-test, whose assumptions were ensured, and the results are given in Table 7.

Table 7. *Pre-process scientific creativity mean scores of the classroom teacher candidates*

Scientific Creativity	*N*	$\bar{X}$	*sd*	*t*	*p*
Control	33	4.86	1.49	1.301	0.182
Experimental	27	5.47	2.09		

p>0.05

When Table 7 is examined, it is seen that before the EDBST process, there is no statistically significant difference between the scientific creativity pretest mean scores of the teacher candidates in the experimental group and the scientific creativity pretest mean scores of the control group [$t(58) = 1.30$, $p>0.05$]. According to this result, it can be interpreted that the students in the experimental and control groups are equal in terms of scientific creativity.

2.2. Is there a significant difference between the post-process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?

Table 8. Post-process scientific creativity mean scores of the classroom teacher candidates

Scientific Creativity	*N*	$\bar{X}$	*sd*	*t*	*p*
Control	33	6.45	2.15	-6.25	0.000*
Experimental	27	11.53	3.75		

*$p<0.05$, **$p<0.01$

After the process MTTF, when looking at Table 8; the experimental group and the average of the final test scores of scientific creativity of teacher candidates recent scientific creativity test of the control group from the average score of higher, it is observed that the difference was statistically significant[$t(39,446) = -6,25$, $p<0.05$]. The effect size of the difference between the posttest mean scores of the experimental and control groups was calculated as *Cohen's d: 1.62* and this value is considered as a large effect according to Cohen (1988). According to this result, it can be interpreted the EDBST process increased the decision-making skills of the classroom teacher candidates in the experimental group at a higher level compared to the control group.

2.3. Is there a significant difference between the scientific creativity dimensions posttest mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?

The data obtained from Scientific Creativity Test (SCT) were analyzed and evaluated by categories in terms of fluency, flexibility and originality, and general scores were obtained. Accordingly, it was seen that there was a statistically significant difference between the posttest scientific creativity mean scores of the control and experimental groups. In addition, while calculating the mean SCT scores, it was examined whether there was a difference between the mean scores in the fluency, flexibility and originality dimensions and the descriptive statistics belonging to the mean scores are given in Figure 2. The posttest mean scores for the fluency, flexibility and originality sub-dimensions of SCT are shown in Figure 2.

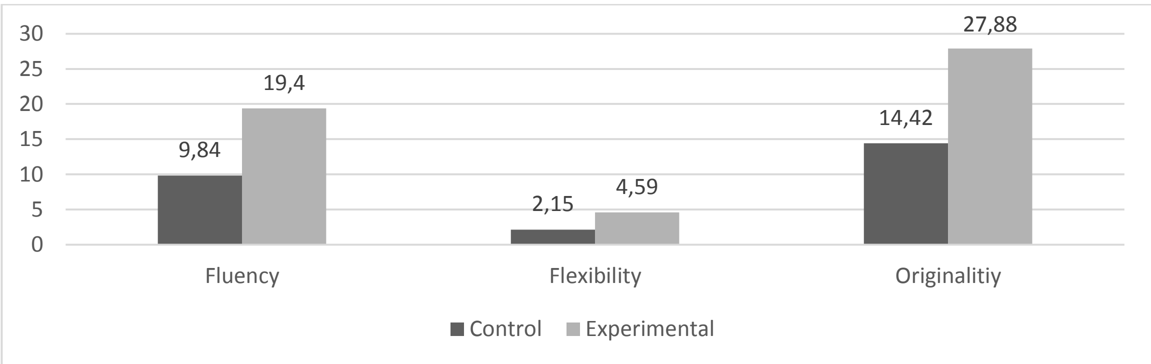


Figure 2: Post-test mean scores regarding the scientific creativity dimensions (fluency, flexibility, originality)

When Figure 2 is examined, it is seen that the SCT posttest scores of the classroom teacher candidates in the experimental and control groups increased in favor of the experimental group in terms of fluency, flexibility and originality. The arithmetic mean, standard deviation, minimum and maximum values related to the SCT posttest of the classroom teacher candidates are given in Table 9.

Table 9. Measures of central tendency scientific creativity dimensions

Scientific Creativity Dimensions	Posttest	*N*	$\bar{X}$	*sd*	*Min.*	*Max.*
Fluency	Control	33	9.84	2.96	5.00	16.00
	Experimental	27	19.40	7.59	9.00	42.00
Flexibility	Control	33	2.15	1.43	0.00	5.00
	Experimental	27	4.59	1.73	2.00	8.00
Originality	Control	33	14.42	7.04	5.00	33.00
	Experimental	27	27.88	12.29	12.00	60.00

When the scores that the teacher candidates received from the fluency sub-dimension of the posttest of SCT were examined in Table 9, it was seen that the scores of the teachers in the control group were between 5.00-16.00 and this distribution was in the range of 9.00-42.00 in the experimental group. While the mean score is 9.84 in the control group, it is 19.40 in the experimental group. While the score in the flexibility sub-dimension of SCT is between 0.00-5.00 in the control group, it is in the range of 2.00-8.00 in the experimental group.

While the mean score is 2.15 in the control group, it is 4.59 in the experimental group. In the originality sub-dimension of SCT, while the control group is between 5-33, the experimental group is in the range of 12.00-60.00. While the mean score is 14.42 in the control group, it is 27.88 in the experimental group. When evaluated in general, it is observed that there is an increase in all dimensions of SCT in favor of the experimental group.

Whether the difference between the mean scores in the dimensions of SCT was significant was evaluated with one-factor MANOVA. When the test assumptions were examined before performing the analysis, two extreme values were excluded from the experimental group to provide one-way and multivariate normality. The mean scores received from the scientific creativity sub-dimensions by the classroom teacher candidates to whom the courses were taught according to the 5E learning model and those to whom the courses were taught with the EDBST embedded in the 5E learning model were compared with one-factor MANOVA and the findings obtained are given in Table 10.

Table 10. Comparison of the sub-dimensions of SCT through MANOVA

Scientific Creativity Dimensions	Posttest	*N*	$\bar{X}$	*sd*	*df*	*t*	*p*	*d*
Fluency	Control	33	9.84	2.96	32	-6.164	0.000*	1.65
	Experimental	27	19.40	7.59	26			
Flexibility	Control	33	2.15	1.43	32	-5.954	0.000*	1.53
	Experimental	27	4.59	1.73	26			
Originality	Control	33	14.42	7.04	32	-5.050	0.000*	1.34
	Experimental	27	27.88	12.29	26			

Considering Table 10, whether there was a difference between the groups in terms of fluency, flexibility, and originality, sub-dimensions of SCT at the end of the EDBST process was evaluated through One-Way Multivariate Analysis of Variance (One-Way MANOVA). When the one-way MANOVA results were examined, a statistically significant difference was observed between the fluency, flexibility and originality sub-dimension mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model compared to the control group to whom the courses were taught with the 5E learning model [*fluency* $F(1\text{-}56) = 47.453$, $p<0.001$], [*flexibility* $F(1\text{-}56) = 32.599$, $p<0.001$], [*originality* $F(1\text{-}56) = 27.068$, $p<0.001$]. The effect sizes of the difference between the mean scores of these sub-dimensions are 0.45; 0.36; 0.32, respectively, and these values (*ῄ2>0.14*) are interpreted as a high effect. According to this, it can be interpreted that improvement was observed in the teacher candidates in terms of the fluency, flexibility and originality sub-dimensions of the "trait" dimension of scientific creativity.

2.4) Is there a significant difference between the pre-teaching and post-teaching process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model?

The pre-teaching and post-teaching process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model was calculated and compared with the dependent groups t-test and the results are given in Table 11.

Table 11. Scientific creativity pretest and posttest mean scores of the experimental group trained with EDB

Scientific Creativity	*N*	$\bar{X}$	*sd*	*t*	*p*
Pretest	27	4.86	2.09	-12.252	0.000*
Posttest	27	11.53	3.75		

**p<0.05, **p<0.01*

When Table 11 is examined, it is seen that after the EDBST process, the scientific creativity posttest mean scores of the classroom teacher candidates in the experimental group are higher than their pretest mean scores and the difference is statistically significant [$t(26)= -12.252$, $p<0.05$]. The effect size of the difference between the pretest and posttest mean scores was calculated as *Cohen's d: 2.35*. This value is accepted as large effect according to Cohen (1988). According to this result, it can be interpreted that the EDBST process increased the scientific creativity skills of the classroom teacher candidates in the experimental group at a high level.

2.5) Is there a significant difference between the pre-teaching and post-teaching process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the 5E learning model?

Table12. Scientific creativity pre-test and post-test mean scores of the 5e learning model group

Scientific Creativity	*N*	$\bar{X}$	*sd*	*t*	*p*
Pretest	33	5.47	1.49	2.403	0.022*
Posttest	33	6.45	2.14		

*$p<0.05$

The pre-implementation and post-implementation scientific creativity scores of the classroom teacher candidates in the control group to whom the courses were taught with the 5E learning model were calculated and compared with the dependent t-test and the results are given in Table 12. When Table 12 is examined, it is seen that while the scientific creativity pretest mean scores and posttest mean scores of the teacher candidates in the control group are close to each other, the posttest mean scores are higher and the difference is statistically significant [$t(32)= 2.40$, $p<0.05$]. The effect size of the difference between the pretest and posttest mean scores was calculated as *Cohen's d: 0.41*. This value has a moderate effect, according to Cohen (1988). It can be stated that the medium-level increase in the scientific creativity mean scores of the teachers in the control group results from the courses taught with the 5E learning model in accordance with the constructivist education understanding. The teacher candidates participated in the process activities in the step of discovering the 5E learning model and reached explanations by performing various activities. It can be stated that this process increased the creative thinking of the teachers. From this point of view, it can be interpreted that the EDBST process has a high level of effect on the scientific creativity scores of the classroom teacher candidates.

3) How to do the engineering design-based process skill mean scores of the pro-change at the end of the EDBST embedded in the 5E learning model where six different designs were made?

3.1) Is there a significant difference between the engineering design-based process skill mean scores of the classroom teacher candidates at the end of EDBST embedded in the 5E learning model where six different designs were made?

During the EDBST process, the engineering design-based process skill mean scores obtained as a result of six different designs of the teacher candidates in the experimental group were calculated and the results are presented in Table 13. When Table 13 is examined, the change in the mean scores of the classroom teacher candidates in terms of the individual engineering design-based process skill in the EDBST process was determined and presented in Figure 3.

Table13.Engineering design-based process skill mean scores

Group No	*Design 1*	*Design 2*	*Design 3*	*Design 4*	*Design 5*	*Design 6*
1	12	11	10	15	19	20
2	15	16	18	19	20	20
3	12	13	18	16	19	19
4	8	12	13	15	19	20
5	9	14	15	14	21	22
6	11	17	16	19	22	22
Mean Score	11.16	13.86	15	16.33	20	20.5

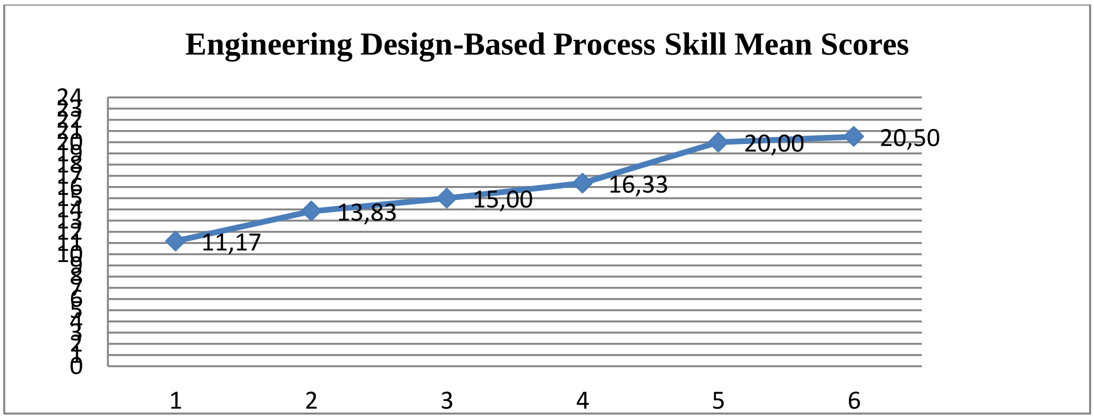


Figure 3: The change between the mean scores related to the engineering design-based process skill

According to Figure 3, the engineering design-based process skill mean scores of the classroom teacher candidates in the experimental group were 11.17 in the first design, it increased to 20.50 in the final design. The teacher candidates to whom the EDBST was applied performed 6 different engineering designs throughout the process. The designs performed by the teachers in the experimental group were evaluated with the engineering design process evaluation rubric and whether there was a difference between the mean scores was investigated with one-way repeated measures ANOVA. The findings obtained as a result of the comparison of the engineering design-based process skill mean scores by using one-way repeated measures ANOVA are presented in Table 14.

Table 14. Results for the comparison of the engineering design-based process skill mean scores

Design	Sum of Squares	sd	Square of Means	F	p	Eta-Square (ή2)
Design	1644.825	2.496	672.155			
Error	342.481	64.902	5.277	127.377	.000*	.830
Total	1987.306	67.398	677.432			

($F_{(2.496;\ 64.902)}$=127.377, p<0.001, ή2=.830)

Looking at Table 14, it was determined that there was an increase in the average scores of experimental classroom teacher candidates for engineering design based process skill from the first design to the last design and that the difference between the average scores was statistically significant (*p<0.05*). The effect size of the difference between the engineering design-based process skill mean scores was calculated as *0.83* and this value was interpreted as a large effect since it was (*ή2>0.14).* At the end of the six designs in which EDBST process was applied, the teacher candidates' engineering design-based process skill mean scores increased significantly. Accordingly, it can be interpreted that the teacher candidates in the experimental group improved their engineering design-based process skills as a result of the implementations. The paired comparisons of the engineering design-based process skill mean scores of the teachers in the experimental group were performed with the Bonferroni test and the results are given in Table 15.

Table 15. Engineering design-based process skill mean scores with the Bonferroni test

Design Pairs	*Mean Difference*	*Sig.*
Designs 1-2	-2.407	0.001*
Designs 1-3	-3.667	0.000*
Designs 1-4	-5.000	0.000*
Designs 1-5	-8.556	0.000*
Designs 1-6	-9.037	0.001*
Designs 2-3	-1.256	0.077
Designs 2-4	-2.593	0.000*
Designs 2-5	-6.148	0.000*
Designs 2-6	-6.630	0.000*
Designs 3-4	-1.333	0.139
Designs 3-5	-4.889	0.000*
Designs 3-6	-5.370	0.000*
Designs 4-5	-3.556	0.000*
Designs 4-6	-4.037	0.000*
Designs 5-6	-0.481	0.000*

**p<0.05, **P<0.01*

When Table 15 is examined, the differences between the engineering design-based process skill mean scores of the teacher candidates in the experimental group during the EDBST process are seen. According to the analysis results, while there is no statistical difference between the mean scores of the design 3 and the designs 2 and 4, there is a statistically significant difference between the design 3 and the designs 5 and 6. All other designs differ from the previous design in terms of both mean score and significance. The increase in the first two designs slowed down in the middle of the continuous and started to rise again. According to this result, it can be interpreted that engineering design-based process skills are gained over time.

Conclusion and Discussion

In this study, the effect of the EDBST process on the decision-making skills and scientific creativity of classroom teacher candidates was investigated. Accordingly, it was concluded that the pretest mean scores of the teacher candidates in the experimental and control groups were close to each other before the EDBST process, and the mean scores increased significantly in favor of the experimental group after the process. When the literature was examined, there were not many studies investigating the effect of design-based teaching processes on decision-making skills. Similarly, to the results of this study, Bozkurt (2014) found that engineering design-based teaching had a positive and large effect on science teachers' decision-making skills. In the study conducted by Ercan (2014) with the primary school 7th-grade students, it was determined that the engineering design-based science teaching applied in the "Force and Motion" unit increased decision-making skills, engineering disciplines and academic achievement levels of the students. In addition, Ercan and Bozkurt (2013) stated that, after the engineering design-based science teaching, positive developments were observed in the decision-making skills of secondary school students. In 2006, NAE and NRC engineering committee prepared the K-12 curriculum that included design-based practices in science teaching in the USA. It is seen that science, mathematics, engineering and technology disciplines are integrated in the K-12 curriculum in order to prioritize the engineering discipline (NAE & NRC, 2009). In the engineering design process, which is increasing in importance, problems are identified first; after the problem is identified, solutions are offered; then the most appropriate solution is decided by making selections in accordance with the criteria and limitations of the problem. Afterward, a prototype is created and the design presented as a solution offered is performed and tested (Koehler et al., 2005). It is highly important to be able to solve problems in the engineering design process and to decide appropriate solutions while doing this (Jonassen, 2011; Kayser 2011). In their study, Dym et al. (2002) compared different solution suggestions in the problem-solving process. It is stated that there are some difficulties when comparing solution suggestions. However, it can be an effective decision-making process. In this study, it is also seen that the decision-making skill mean scores of the classroom teacher candidates increased as a result of DMST in the EDBST process. It can be concluded that the EDBST process affects teachers' decision-making skills considerably and positively. It is thought that teacher candidates can manage an effective decision-making process.

When the results related to the effect of the EDBST process on scientific creativity of classroom teacher candidates were examined, it was observed that the experimental and control groups' scientific creativity pretest mean scores were close to each other before the process and these mean scores increased significantly in favor of the experimental group after the process. When the studies conducted on the subject were examined, Hacıoğlu (2017) determined that the 14-week engineering design-based science practices significantly improved scientific creativity and critical thinking skills of science teacher candidates. Similarly, in their study conducted in Malaysia et al. (2015) conducted an 8-hour project-based STEM workshop with 21 preservice teachers and 21 teachers in service. In the light of the questionnaires, interviews and classroom discussions before and after the practices, it was seen that the STEM activities contributed to the students in terms of generating creative ideas. Moreover, Hacıoğlu (2017) found a significant difference in favor of the experimental group in fluency, flexibility and originality sub-dimensions of SCT. In the applied study on creative thinking in science education, Koray (2014) obtained results in favor of the science teacher candidates in the experimental group in terms of the fluency, flexibility, elaboration and originality sub-dimensions. Kaya (2018) examined the effect of STEM education on science teaching third-grade teacher candidates' creativity and self-regulation skills and specified that these skills developed positively after the implementation. Yıldırım and Türk (2018) continued the 12-week STEM education with 40 teacher candidates in the 2016-2017 academic year and received their opinions regarding STEM education. As a result of the research, the classroom teacher candidates stated that "STEM practices can develop characteristics such as creativity, curiosity, self-confidence and responsibility in students". These studies reveal that there is a connection between engineering design processes and creative thinking. In engineering processes, opinions such as creativity, cooperation, ethics and optimism are also included (NAE & NRC, 2009). When the literature is analyzed, the lack of studies, where STEM activities are applied at the primary school level and the effect of these activities on students' scientific creativity, draws attention. The study of Genek (2018) examined the scientific creativity levels of the first, third and fourth-grade students, who took the STEM course, according to various variables and found that their scientific creativity changed according to their grade levels. Yavuz (2019) conducted science courses in accordance with STEM content with fourth-grade students and concluded that STEM practices were effective in improving students' creativity levels and 21st-century skills. In this study, it was also observed that the teacher candidates had positive developments in their scientific creativity levels during the EDBST process. In addition, positive developments were observed in the teacher candidates in the fluency, flexibility and originality sub-dimensions of the "trait" dimension of creative scientific thinking. Therefore, it can be stated that EDBST practices have a positive and large effect on teacher candidates' scientific creativity levels. In addition, the literature also put forwards that problem solving, producing hypotheses and creating designs in the engineering design process are related to scientific creativity (Lin et al., 2003). Grosul (2010) associates the transfer of creativity to life by combining it with scientific theories with scientific creativity. Similarly, Dağlıoğlu (2010) defines creativity as individuals' thinking of new things, integrating these into their lives and creating innovations. These statements reveal that scientific creativity is used in engineering design processes. In this study, it is thought that classroom teacher candidates can be more successful in managing their scientific processes based on their interpretation that their scientific creativity develops positively, they can transfer innovation to their lives more easily and they will ground creativity on scientific foundations in the engineering design process.

When the results obtained from the data in the engineering design process forms, where the phases of the EDBST process were included, were examined, it was observed that there was a significant difference between in the following weeks and past weeks in terms of the engineering design-based process skills mean scores obtained from six different EDBST practices. Although there was an increase in the mean scores of the design (Effects of Force) in the 3rd week compared to the previous weeks, it was not significant. It is interpreted that this may have resulted from the fact that the content of the learning outcomes in the unit made the design process difficult and the process wasn't understood by the teacher candidates in the course of time. The aim of educating students with engineering design-based processes is to develop products by finding quality solutions to problems by benefiting from an engineering rather than building something and improving their decision-making skills in this process. The success of this process depends on three factors: Students are actually like engineers, teachers should listen to their students and classroom environments need to be adjusted for an effective design process (Hynes et al., 2011). From this perspective, the studies to be conducted about engineering design process are very important. Breiner et al. (2012) stated that STEM education was provided as a discipline integration in the process of thinking like a scientist and an engineer in a study in a university in the USA with STEM education facultyi. Furtermore, in their study, Difrancesca, Lee and McIntyre (2014) expressed that STEM education process was very beneficial for primary school students in terms of finding solutions to the problems they face in daily life, improving their engineering skills and their careers in this field. English and King (2015) examined the design process of the fourth-grade children in the first year of their three-year longitudinal study. The children (problem scope, idea generation, design and production, design evaluation, redesign) performed the design and redesign of a 3D model plane according to the engineering design phases. Particularly, it was seen that the students used STEM discipline knowledge in the last two phases (design evaluation and redesign). It is considered highly important that the engineering design process is a whole; this process is tested and revised when necessary. Similarly, Çorlu and Çallı (2017) explained this process as the use of knowledge in daily life with an interdisciplinary approach according to knowledge-based life problems. In the study conducted by Bozkurt (2014) with the science teacher candidates within the scope of the Science Laboratory Application-I course, it was seen that the science education based on engineering design developed the decision-making and scientific process skills of the participants. It is considered that this education will be very useful for a primary and secondary school science course. Furthermore, Eroğlu and Bektaş (2016) interviewed five science teachers in three different secondary schools and examined the opinions of teachers about STEM-based course activities. Accordingly, it was observed that the teachers associated STEM-based education with the field of physics and established a relationship between science and technology, mathematics and engineering. In another study, semi-structured interviews were conducted with six science teacher candidates regarding the design-based process. As a result, the teachers mentioned about the strengths of the process and stated that the engineering design process contributed to permanent learning (Altan et al., 2016). Furthermore, Altaş (2018) applied the course plans prepared according to STEM education to classroom teacher candidates and investigated their engineering and technological perceptions of using the engineering design process steps. The results of this research also showed that classroom teacher candidates improved in terms of their skills to use engineering design process steps and they would be able to these in their daily lives. The classroom teacher candidates also improved themselves in areas such as managing this process effectively and producing different designs. In their research, Çalışıcı and Sümen (2018) examined the metaphors of 138 teacher candidates about the STEM education approach. The teachers found STEM education very useful by regarding STEM as an ever-evolving and popular educational approach. In their research that they experimentally conducted with the STEM activities, Karışan and Yurdakul (2017) observed positive developments in the attitudes of the experimental group students towards STEM. Seçkin-Kapucu and Karakaya-Özyer (2019) enabled secondary school students to self-evaluate the design process in terms of various variables. The research was carried out in two stages, in the fall and spring term of the 2018-2019 academic year. In the first stage, the scale was developed and in the second stage, the relationship between the scale and other variables was examined. The first stage of the study was conducted with 530 students from 7th and 8th grades, whereas 447 students participated in the second stage. The relationship between perception for problem solving skills and decision-making attitudes, which are considered important in the design process, were examined. As a result of the research, it was determined that the problem solving perception and the cautious selective decision-making style contributed significantly to the self-evaluation of the design process. Similarly, as a result of this study, a statistically significant difference was found between the experimental group in which the design process was applied and the control group in terms of decision-making skills. The design process positively affected pre-service teachers' decision-making skills.

In this study conducted according to the content integration of STEM, in the MTTFÖ process, teacher candidates' decision-making skills, scientific creativity and design-based process skills were positively affected. As a result of this research, the targeted research problems are considered to be answered as expected. Grounding the design with scientific researches in the middle of the plane in Wendell's (2008) design/scientific research-inquiry approach prepared for constructivist science courses was effective in this study. In our country, the science education curriculum based on research-inquiry has been renewed in line with the needs of the age and it has been tried to be integrated with science and engineering skills. With this study, teacher candidates will be able to use the STEM education approach familiarly with the engineering design process and will use STEM education in their teaching processes by understanding the contribution of this process to the 21st-century skills.

Recommendations

In order to overcome some limitations encountered in this study, the information about the process can be provided to the participants at least three weeks before starting the practices for a better understanding of the EDBST process in the long-term practices. In order to benefit from the mathematics discipline in the EDBST process, daily life problems related to mathematics learning outcomes can be identified. In addition, simpler robotic coding, which includes ready coding such as block coding and maker sets, can be used to increase technology awareness among students. Similarly, the EDBST process can be performed with primary school students. In the studies to be conducted, support can be received from primary school students and their teachers. Appropriate environments and materials for STEM education can be provided in schools and universities. The main target in similar practices is to ensure that students are familiar with early engineering education and become productive individuals in their learnings to be performed in accordance with daily life problems. In our country, engineering design-based training to be provided at the primary school level are needed to develop this field.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors

Acknowledgements or Notes

This study was derived from the first author's doctoral thesis. Within the scope of this research, Gazi University Scientific Research Project coded 04 / 2018-03 provided support on materials to be used during STEM education.

References

Acar, D. (2018). *FETEMM eğitiminin ilkokul 4. sınıf öğrencilerinin akademik başarı, eleştirel düşünme ve problem çözme becerisi üzerine etkisi*[*The effect of STEM education on the academic success, critical thinking and problem solving skills of the elementary 4th grade stude*nts]. Doctoral Thesis, Gazi University, Institute of Educational Sciences, Ankara.

Adams, M. (2015). A cultural historical theoretical perspective of discourse and design in the science classroom. *Cultural Studies of Science Education*, *10*(2), 329-338.

Altan, E. B., Yamak, H., & Kırıkkaya, E. B. (2016). A proposal of the STEM education for teacher training: design based science education. *Trakya Journal of Education*, *6*(2), 212-232.

Altaş, S. (2018). *STEM eğitimi yaklaşımının sınıf öğretmeni adaylarının mühendislik tasarım süreçlerine, mühendislik ve teknoloji algılarına etkisinin incelenmesi*[*Investigation of the effects of STEM education approach on the perceptions of classroom teaching candidates about engineering design processes and about engineering and technology*]. Master Thesis, Muş Alparslan University, Institute of Science, Muş.

Aslan-Tutak, F., Akaygün S., & Tezsezen S. (2017). Collaboratively learning to teach STEM: Change in participating preservice teachers' awareness of STEM. *Hacettepe University Journal of Education, 32*(4), 794-816.

Batı, K. (2014). *Modellemeye dayalı fen eğitiminin etkililiği; öğrencilerin bilimin doğası görüşleri ile eleştirel düşünme becerilerine etkisi*[*The effectiveness of modeling based elementary science education; It's effects on students? views about nature of science and critical thinking abilities*]. Doctoral Thesis, Hacettepe University Institute of Educational Sciences, Ankara.

Bozkurt, E. (2014). *Mühendislik tasarım temelli fen eğitiminin fen bilgisi öğretmen adaylarinin karar verme becerisi, bilisel süreç becerileri ve sürece yönelik algılarına etkisi*[*The effect of engineering design based science instruction on science teacher candidates' decision making skills, science process skills and perceptions about the process]*. Doctoral Thesis, Gazi University, Institute of Educational Sciences, Ankara.

Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics, 112*(1), 3-11.

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P- 12 classrooms. *Journal of Engineering Education, 97*(3), 369-387.

Brown, C., Taylor, C., & Ponambalum, L. (2016). Using design-based research to improve the lesson study approach to professional development in camden (London). *London Review of Education, 14*(2), 4-24.

Büyüköztürk, S., Kılıç Çakmak, E., Akgün, Ö. E., Karadeniz, S., & Demirel, F. (2012). *Bilimsel Araştırma Yöntemleri[*Scientific Research Methods]. (18nd Ed.). Ankara: Pegem Academy.

Bybee, R. W., (2010). Advancing STEM Education. A 2020 Vision. *Technology and Engineering Teacher, 70*(1) 30-35.

Christensen, L. B. Johnson, B., & Turner, L. A. (2015). *Araştırma yöntemleri: Desen ve analiz[*Research methods: Pattern and analysis]. Ankara: Anı Publishing.

Cohen, J. C. (1988). *Statistical power analysis for the behavioral sciences* (2nd Ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Çorlu, M. S., & Çallı, E. (2017). *STEM kuram ve uygulamalarıyla fen, teknoloji, mühendislik ve matematik eğitimi* [*Science, technology, engineering and mathematics education with STEM theory and applications*]. İstanbul: Pusula Publishing.

Dağlıoğlu, H. E. (2010). Yaratıcılık, hayal gücü ve zekâ ilişkisi [Creativity, imagination and intelligence]. E. Çelebi Öncü (Ed.) *Erken çocukluk döneminde yaratıcılık ve geliştirilmesi[Creativity and development in early childhood*] in (s. 48-82). Ankara: Pegem Academy.

DiFrancesca, D., Lee, C., & McIntyre, E. (2014). Where is the" E" in STEM for young children? engineering design education in an elementary teacher preparation program. *Issues in Teacher Education*, *23*(1), 49-64.

Drake, S. M., & Burns, R. C. (2004). *Meeting standards through integrated curriculum*. USA: ASCD.

Dym, C. L., Wood, W. H., & Scott, M. J. (2002). Rank ordering engineering designs: pairwise comparison charts and Borda counts. *Research in Engineering Design*, *13*(4), 236-242.

English, L. D., & King, D. T. (2015). STEM learning through engineering design: fourthgrade students' investigations in aerospace. *International Journal of STEM Education*, *2*(1), 14.

Ercan, S. (2014). Fen eğitiminde mühendislik uygulamalarının kullanımı: tasarım temelli fen eğitimi[The use of engineering applications in science education: design based science education]. *Necatibey Faculty of Education, Electronic Journal of Science and Mathematics Education (EFMED),9*(1), 128-164.

Eroğlu, S., & Bektaş, O. (2016). STEM eğitimi almış fen bilimleri öğretmenlerinin STEM temelli ders etkinlikleri hakkındaki görüşleri[Ideas of Science Teachers took STEM Education about STEM based Activities]. *Journal of Qualitative Research in Education, 4*(3), 43-67.

Fortus, D., Dershimer, R. C., Krajcik, J. S., Marx, R. W., ve Mamlok-Naaman, R. (2004). Design-based science and student learning. *Journal of Research in Science Teaching, 41*(10), 1081-1110.

Genek, S. (2018). *STEM eğitimi uygulanan ilkokul öğrencilerinin bilimsel yaratıcılık düzeylerinin incelenmesi[Investigation of scientific creativity levels of elementary school students who enrolled in a STEM program*]. Master Thesis, Bahçeşehir University, Institute of Educational Sciences, İstanbul.

Gencer, A. S. (2017). Fen eğitiminde bilim ve mühendislik uygulaması: Fırıldak Etkinliği. Journal of Inquiry Based Activities, *5*(1), 1-19.

Gravetter, F. L., & Wallnau, L. B. (2013). *Statistics for the behavioral sciences (9th ed*.). Belmont, CA: Wadsworth.

Grosul, M. (2010). *In search of the creative scientific personality.* Master's Thesis, San Jose State University The Faculty of the Department of Psychology, California.

Hacıoğlu, Y. (2017). *Fen, teknoloji, mühendislik ve matematik (STEM) eğitimi temelli etkinliklerin fen bilgisi öğretmen adaylarının eleştirel ve yaratıcı düşünme becerilerine etkisi*[*The effect of science, technology, engineering and mathematics (STEM) education based activities on prospective science teachers'* *critical and creative thinking skills*]. Doctoral Thesis, Gazi University, Institute of Educational Sciences, Ankara.

Hu, W., & Adey, P. (2002). A scientific creativity test for secondary school students. *International Journal of Science Education*, *24*(4), 389-403.

Hynes, M., Portsmore, M., Dare, E., Milto, E., Rogers, C., Hammer, D., & Carberry, A. (2011). Infusing engineering design into high school STEM courses. *Publications,* 1-7.URL address: https://digitalcommons.usu.edu/ncete_publications/165.

Jonassen, D. H. (2011). Design problems for secondary students. *National Center for Engineering and Technology Education*.

Kadayıfçı, H. (2008). *Yaratıcı düşünmeye dayalı öğretim modelinin öğrencilerin maddelerin ayrılması ile ilgili kavramları anlamalarına ve bilimsel yaratıcılıklarına etkisi*[*The effect of an instructional model based on creative thinking on students' conceptual understanding of separation of matter subject and their scientific creativity]*. Doctoral Thesis, Gazi University, Institute of Educational Sciences, Ankara.

Kaptan, F., & Kuşakcı, F. (2002). *Fen öğretiminde beyin fırtınası tekniğinin öğrenci yaratıcılığına etkisi* [*The effect of brainstorming technique on student creativity in science teaching]*. V. National Science and Mathematics Education Congress Proceedings,197-202.

Karahan, E., Canbazoglu-Bilici, S., & Unal, A. (2015). Integration of media design processes in science, technology, engineering, and mathematics (STEM) education. *Eurasian Journal of Educational Research*, *60*, 221-240.

Karışan, D., & Yurdakul, Y. (2017). The effects of microprocessors based science technology engineering and mathemetics (STEM) investigations on 6th grade students' attitudes towards these subject areas. *Adnan Menderes University Faculty of Education Journal of Educational Sciences*, *8*(1), 37-52.

Kaya, M. E. (2018). *STEM uygulamalarının fen bilgisi öğretmen adayları öz düzenleme ve yaratıcılığına etkisi* [*The impact on the creativity and self-educational skills of student education teacher candidates*]. Master Thesis, Erzincan Binali Yıldırım University, Institute of Science, Erzincan.

Kayser, T. A. (2011). *Building team power: how to unleash the collaborative genius of teams for increased engagement, productivity, and results*. NY: McGraw-Hill.

Koçak, B. (2019). Fe*n bilimleri, matematik ve sınıf öğretmen adaylarının FeTeMM öğretimine ilişkin yönelimleri*[*Science, mathematics and primary preservice teachers' intention on STEM teaching*]. Master Thesis, Akdeniz University, Institute of Educational Sciences, Antalya.

Koehler, C., Faraclas, E., Sanchez, S., Latif, S. K., & Kazerounian, K. (2005). Engineering frameworks for a high school setting: guidelines for technical literacy for high school students. ASEE Conference & Exposition, page,10, 1.

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., & Ryan, M. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting learning by design (tm) into practice. *The Journal of the Learning Sciences*, *12*(4), 495-547.

Koray, Ö. (2004). The influence of science education based on creative thinking on creativity of preservice teachers. *Educational Administration: Theory and Practice*, *10*(4), 580-599.

Lin, C., Hu, W., Adey, P., & Shen, J. (2003). The influence of CASE on scientific creativity. *Research in Science Education*, *33*(2), 143-162.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: a sourcebook.* Uk: Sage.

MoNE (2013). T.C. Milli Eğitim Bakanlığı Talim Terbiye Kurulu Başkanlığı,*ilköğretim fen bilimleri dersi (4, 5, 6, 7 ve 8. Sınıflar) öğretim programı[Board of Education and Discipline, elementary science lesson (4th, 5th, 6th, 7th and 8th grades) curriculum]*. Ankara: Devlet Kitapları Müdürlüğü.

MoNE (2018). T.C. Milli Eğitim Bakanlığı Talim Terbiye Kurulu Başkanlığı, *ilköğretim fen bilimleri dersi (4, 5, 6, 7 ve 8. Sınıflar) öğretim programı[Board of Education and Discipline, elementary science lesson (4th, 5th, 6th, 7th and 8th grades) curriculum]*. Ankara: Devlet Kitapları Müdürlüğü.

Moore, T. J., Glancy, A. W., Tank, K. M., Kersten, J. A., Smith, K. A., & Stohlmann, M. S. (2014). A framework for quality K-12 engineering education: Research and development. *Journal of Pre-College Engineering Education Research (J-PEER)*, *4*(1), 2.

National Academy of Engineering [NAE] & National Research Council [NRC] (2009). *Engineering in K-12 education understanding the status and improving the prospects.* Edt. Katehi, L., Pearson, G., & Feder, M. Washington, DC: National Academies.

National Aeronautics and Space Administration [NASA], 2015. *Let It Glide: Facilitation Guide.* URL address:https://www.nasa.gov/sites/default/files/files/EDC02_Let_It_Glide_Facilitation_Guide_FINAL.pdf.

Resnick, M. (2002). Rethinking learning in the digital age. In G. Kirkman (Ed.) *The Global information technology report: Readiness for he networked World* (pp. 32-37). Oxford: Oxford University.

Rogers, C., & Portsmore, M. (2004). Bringing engineering to elementary school. *Journal of STEM Education: Innovations and Research, 5(*3/4), 17.

Rosenthal, R., & Rosnow, R. L. (1991). *Essentials of behavioral research: Methods and data analysis (2nd Ed.).* New York: McGraw Hill.

Salvucci, S., Walter, E., Conley, V., Fink, S., & Saba, M. (1997). *Measurement Error Studies at the National Center for Education Statistics.* (NCES 97-464). Washington, DC: National Center for Education Statistics.

Schwartz, R. S., Akom, G., Skjold, B., Hong, H. H., Kagumba, R., & Huang, F. (2007, April). A change in perspective: Science education graduate students' reflections on learning about NOS. In *International meeting of the National Association for Research in Science Teaching.* New Orleans, LA.

Siew, N. M., Amir, N., & Chong, C. L. (2015). The perceptions of pre-service and in-service teachers regarding a project-based STEM approach to teaching science. *Springer Plus*, *4*(1), 8.

Seckin-Kapucu, M. & Karakaya-Ozyer, K. (2019). Secondary school studensts' selfassessment of design process: A study on scale development and prediction by various variables. *International Online Journal of Educational Sciences*, *11* (4), 296-310.

Tress, G., Tress, B., & Fry, G. (2007). Analysis of the barriers to integration in landscaperesearch projects. *Land use policy*, *24*(2), 374-385.

Uzel, L. (2019). *6. sınıf madde ve ısı ünitesinde gerçekleştirilen mühendislik tasarım temelli uygulamaların öğrencilerin problem çözme ve tasarım becerilerine etkisinin değerlendirilmesi[Evaluation of the impact of engineering design-based activities performed in 6th-grade "matter and heat" unit on problem-solving and design skills]*. Master Thesis, Aksaray University Institute of Science, Aksaray.

Vasquez, J. A., Comer, M., & Sneider, C. (2013). *STEM Lesson Essentials, Grades 3-8: Integrating Science, Technology, Engineering, and Mathematics* (1st ed.). Portsmouth, NH: Heinemann.

Wendell, K. B. (2008). *The theoretical and empirical basis for design-based science instruction for children*. Doctoral Dissertation, Tufts Universty, Massachusetts.

Wendell, K.B., & Rogers, C. (2013). Engineering design-based science, science content performance, and science attitudes in elementary school. *Journal of Engineering Education*, *102*(4), 513-540.

Yavuz, Ü. (2019). *İlkokul fen bilimleri dersinin fen, teknoloji, mühendislik ve matematik (FETEMM) etkinlikleri ile işlenmesi*[*The implementation of the primary school science courses with science, technology, engineering and mathematics (STEM) activities*]. Master Thesis, Afyon Kocatepe University Institute of Social Sciences, Afyon.

Yıldırım, B., & Türk, C. (2018). Pre-service primary school teachers' views about STEM education: An applied study. *Trakya Journal of Education*, *8(*2), 195-213.

Yıldırım, B. (2016). *7. Sınıf fen bilimleri dersine entegre edilmiş fen, teknoloji, mühendislik, matematik (STEM) uygulamaları ve tam öğrenmenin etkilerinin incelenmesi*[*An examination of the effects of science, technology, engineering, mathematics (STEM) applications and mastery learning integrated into the 7th grade science course*]. Doctoral Thesis, Gazi University, Institute of Educational Sciences Ankara.

Author(s) Information

Elçin Ayaz
Dicle University,
Diyarbakır, Turkey.
Contact e-mail: elcin.ayazz@gmail.com.
ORCID ID: https://orcid.org/0000-0003-2488-6777

Rabia Sarıkaya
Gazi University,
Ankara, TURKEY.
ORCID ID: https://orcid.org/0000-0001-9247-8973

Journal of Education in Science, Environment and Health
Volume 7, Issue 4, 2021 https://doi.org/10.21891/jeseh.990498

Distance STEM Educators' Perceptions of Teachers' Role

M.Said Dogru, Fatih Yuzbasioglu

Article Info

Article History

Published:
01 October 2021

Received:
03 January 2021

Accepted:
31 August 2021

Keywords

STEM Education
Online education
Distance education
Distance STEM education

Abstract

STEM education has an important place in recent studies. With the Covid 19 pandemic, distance education applications have gained importance all over the world. STEM education applications have also turned into distance STEM education with the Covid-19 pandemic. The purpose of this study is to better understand STEM teachers' perceptions of online group education and how they perceive group education expectations. In this study, semi-structured interviews were conducted with secondary school STEM teachers. The interview was aimed at illuminating teachers' perceptions of the role and purpose of teachers, and students' expectations from a group science lesson. Themes arising from the thematic analysis of interviews were determined. The themes that emerged from the analysis are as follows: Teachers' perceptions of their teaching role, teachers' perceptions of students' psycho-social needs, and teachers' perceptions of students' educational needs. Promoting student interaction in online synchronous education was identified as a challenge. Besides, some discrepancies were observed between teachers' perceptions of students learning expectations and their preferred approaches, and it was found that students expect a didactic experience rather than an interactive one.

Introduction

In recent years, developments in education have focused on improving the student experience to maximize student achievement. For example, the *Teaching Excellence Framework* is a serious driving force aiming to deliver excellent education and ensure face-to-face accountability (Campbell et al., 2019). Education should provide an environment that enables students to develop the 'social skills' they will need in all areas of their lives. This environment must include the vital development of the student's learning ability as well as critical thinking, teamwork, and analysis skills (Frankham, 2017). Whether it is campus-based or distance-based, the traditional way educational institutions address this aspect of education is to provide education in groups. While educators consider the need to develop social skills for student groups to enrich the learning experience, they also aim to ensure that the needs of individual students are met (Westhuizen, 2016; Wilson, 1996). Understanding the perceptions of teachers and students can give us insights into the discrepancies between expectations and practice. By examining such differences, it can enable staff to develop more effective forms of support.

During the COVID-19 pandemic, which first appeared in 2019 and affected the whole world, the distance education system was introduced in many countries, including the USA and European countries (Can, 2020). With this change, teachers had the opportunity to change the design and implementation of teaching materials, including style and content. In this study, we look at teachers' current perceptions of the role and purpose of tutorials in STEM disciplines at various institutions, as well as teachers' understanding and perceptions of students' expectations. The problems that arise are related to interdisciplinary and cross-sectoral relations, and particularly to institutions offering distance or online education.

Educational Context

During the COVID-19 pandemic, which the whole world faced, educational institutions have become distance education providers and their role is to interact with students one-on-one, help students with their homework, and help them work on their own, and contribute to group tutorials. These tutorials can be face-to-face, online synchronized, or a mix of both. Teachers decide on the content of in-class activities and which teaching method to use to support students at certain points in a course in most disciplines (Campbell et al., 2019).

Although previous studies have been conducted to analyze the higher-level objectives of the tutorials (Thorpe, 2002), it is thought that there are perceptions and practical approaches of experienced STEM teachers who determine the content and style of educational presentations for individual student groups. As such views emerge as a result of environmental factors and teachers’ experience, students' expectations from teaching will likely change over time (Sander et al., 2007).

The use of synchronous communication technologies such as "BigBlueButton", which enables both voice and written communication simultaneously while teaching on a virtual board is increasing in online education. While such technologies contain some features of face-to-face education, they also offer some features specific to online education (White et al., 2010; Chen et al., 2005; Cunningham, 2014; Wang et al., 2017). Findings from studies with secondary school students continuing online distance education in Turkey revealed that online synchronous courses have shortcomings in subjects such as student interaction, social presence of students in lessons and student participation (Akgül & Oran, 2020; Canpolat & Yıldırım, 2021). The findings of Cavanaugh (2001)'s meta-analysis study on online education in secondary school were found to be like those of studies in Turkey. Although findings indicate that the developments in this area have been slow, teachers working in this field can still overcome students' social presence problems (Haresnape et al., 2020).

The characteristic feature of group activities in the online education model is that student participation is optional. However, teachers state that the rate of participation is generally low and many students prefer not to participate in the online courses. Therefore, it is very important to understand students' perceptions about group education. Although it is not the primary purpose of the current study, revealing student expectations as perceived by teachers may also provide useful information. To discover other variables that shape the views of teachers, the researchers adopted a holistic approach to identify factors that influence teachers' perceptions of the purpose of courses in the online education system. The purpose of this study is to better understand STEM teachers' perceptions of online group education and how they perceive group education expectations.

Table 1. Semi-structured interview questions (Campbell et al., 2019)

Category	Question
Teacher background (Closed questions)	Which courses did you teach?
	Did you study in other faculties, such as STEM?
	What teaching experience do you have?
Teaching purposes (Open-ended questions)	What are your thoughts on group teaching?
	What was your understanding of the purpose of group teaching?
	Have your expectations for group teaching goals changed or improved since you first started?
Delivery mode (Closed questions)	Can you mention us the mode of delivery for your group tuition?
	How do you manage group activities in your course?
Objectives (Open-ended questions)	What are your objectives for group teaching?
	To what extent did your course team guide you about the goals of group teaching?
	What factors do you consider when deciding what to include in their tutorials?
	When will you present the tutorials?
Other opinions (Open-ended questions)	In terms of the course team, your line manager, and other teachers, what are your thoughts on group teaching?
Student views perceptions (Open-ended questions)	How do you believe group teaching benefits students?
	What do you believe students perceive the purpose of group teaching to be?
	How does this affect the way you plan your education?

Method

In the data collection process, a qualitative approach consisting of semi-structured recorded interviews with 50 STEM teachers from different institutions who have taken STEM courses and voluntarily participated in the study was adopted. STEM teachers carried out activities related to STEM education to help students better understand the subjects. Some of these activities as follow: Fruit yogurt activity, making a thermometer, recycling machine, and classification of living things. STEM teachers also benefit from group training programs in their courses. The interviews were conducted over the phone, face to face interview and via Zoom's online synchronous software. The participants were asked open-ended and closed questions. A similar pattern was followed in each interview. The history and experience of school education were examined, then focused on the perception of the goals of group education in the context of the school. The teachers were then asked about other perspectives, particularly students' perspectives, and whether this affects their method of educational design and delivery. Campbell et al.'s (2009) interview questions were also used. Table 1 shows the questions used. First, the questions were given to all interviewees, giving them time to think ahead and prepare.

Unlike similar studies (e.g. Jelfs et al., 2009), in the current study, the themes were identified inductively and in an open-ended manner, rather than conforming the analysis to the existing theoretical frameworks in advance. Hence, a grounded theory-interpretative approach (Glaser & Strauss, 1967) was adopted to analyze the data. In this respect, an embedded theory-interpreter approach was adopted for the analysis of the data. The Grounded Theory is expressed as creating a new theory through the systematic collection of data and analysis within the research process (Strauss & Corbin, 1998). The GT aims to show the relationships between conceptual categories and to show in detail what theoretical relationships these are (Charmaz, 2002). As in the present study, when the purpose of a study is to learn about the perceptions of participants and the data collected is primarily qualitative and descriptive, the GT provides a perfect structure (Cohen et al., 2001). In this study, the continuous comparative analysis method is adopted. First, the teachers were asked the questions in Table 1 and their opinions were obtained. The data were analyzed immediately after they were collected. In doing this analysis, the teachers in the sample were shared 50/50 by the researchers.

Records of each interview were transcribed and then analyzed by the researchers. The first independent thematic analysis by researchers included an iterative review of scenarios, with occasional review of records. The open coding method was used in the coding of the data obtained during the analysis phase. The constant-comparison analysis was carried out by the researchers carefully to perform the coding and reveal the emerging key themes. To ensure reliability, the coding of the researchers was compared, and the inter-rater reliability was found to be satisfactory. The themes were then obtained from the encoding. These themes are presented in detail in the Findings and Discussion section.

Participants

The ages of the interviewees ranged from 38 to 60 (Table 2). The interviewees were secondary school science teachers who taught STEM. They had attended STEM training courses and received certificates. Many had substantial tutoring knowledge at higher levels, across subjects, and schools (Table 3). They had also participated in out-of-school activities. They also gave training on various subjects such as professional development, vocational education, basic literacy.

Table 2. Participants' age distribution

Age	Number of teachers
0-34	0
35-45	10
46-55	23
56-65	17

Table 3. Participants' teaching experience

Years	Number of teachers
0-5	8
6-10	17
11-20	20
20+	5

Table 4. How many years the participants worked as STEM teachers

Years	Number of teachers
0-5	36
6-10	14

Results and Discussion

The results are analyzed under the heading Emerging Themes which focuses on teacher perceptions, by discussing specific problems arising from the data.

Emerging Themes

Several major themes emerged from the analysis of the teacher interviews. These emerging themes are given in Table 5.

Table 5. Themes emerging from the interviews with teachers

Themes
Teachers’ perceptions of their teaching role
Teachers’ perceptions of students’ psycho-social needs
Teachers’ perceptions of students’ educational needs

Teachers' Perceptions of Their Roles

Facilitator Roles

Relying on the framework of Kember (1997), the teachers interviewed can be said to have a student-centered and learning-oriented approach. All the STEM teachers interviewed within the scope of this study, including technology teachers, stated that they thought they facilitated students' learning. Since all of the teachers who participated in the study were teachers who voluntarily chose to become STEM teachers, they are thought to have a greater interest and a more reflective view of the lesson compared to other teachers. One teacher defined her role as:

> As STEM teachers, our task is to help students learn the subjects in the course more easily. We do this by using materials.

According to King (1993), the role of an educator is to work as a guide. The educator accomplishes this by enabling interaction with the presented material, drawing attention to the importance of facilitation, enabling students to participate on their own, permitting students to share information, and allowing students to make lessons for themselves.

Vocational Skills and Experiences

Providing qualified education to students is the principal purpose of all education systems. One component of qualified education is qualified teachers (Bümen et al. 2012). Teachers who are well-trained professionally can provide positive learning conditions for their students and support them with guided activities in areas where students are struggling (Seferoğlu, 2004). The participants stated that they supported their students by teaching them some concepts and skills. A teacher stated the following on the subject:

> We perform guided practices so that students can benefit from strengthening of concepts.

Vocational experiences help teachers anticipate students' difficulties and misunderstandings and thus design a more appropriate education:

> After learning the system and the course subjects, I can easily guess the points where they will have difficulties and misunderstandings.

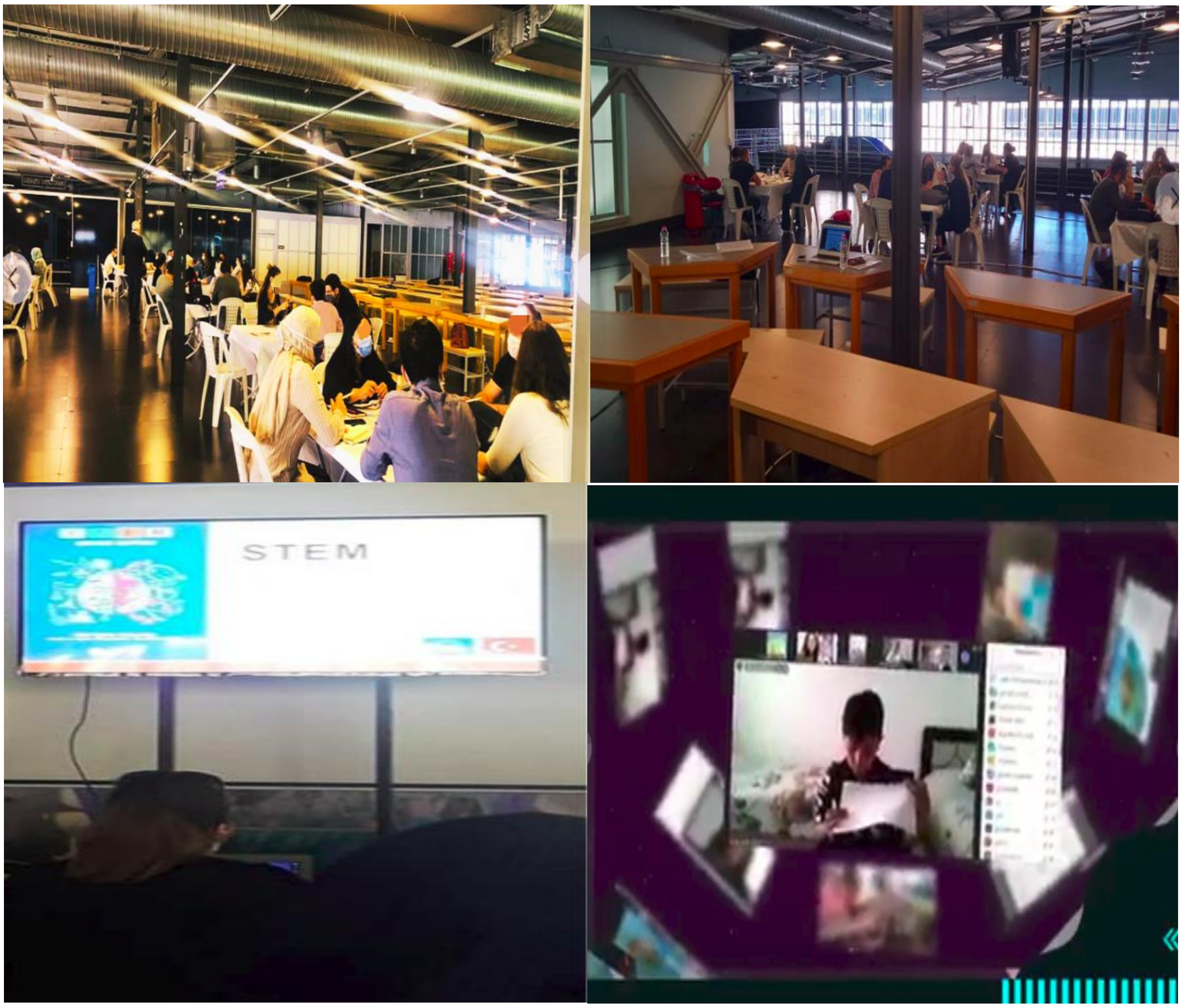


Figure 1. Examples of the applications with teachers

Learning is viewed as an opportunity to develop the fundamental abilities that students will require in their future studies and employment. Such skills are developed through education. Vocational skills are the main ones. Teachers support students in this situation:

> Most students are struggling in areas such as mathematics and science. In the courses, we support students to develop these skills that they will use effectively in their future professional life.

Empathy

Taking advantage of their interactions with students, each teacher who was interviewed tried to express her/his point of view on students' perspectives:

> It's good to get student feedback during the teaching process. But we don't always get feedback from students. In such situations, we try to understand how students feel in class, what subjects they are struggling with, and how I will be more useful to them.

Educational background and experiences

Most of the teachers interviewed said they shaped their courses based on their educational backgrounds and past experiences:

> I still remember how useful some of the lessons I attended were, so I guess I'm trying to model some aspects of my practice around what was useful to me when I was a student.

Assignment

Most of the teachers stated that they expected the students to concentrate on the lessons and prepare their homework. A common answer is as follows:

> Although students are struggling in distance education, we expect that they will participate in the course activities and complete their homework.

Teachers assign their students homework to improve their learning experience. However, the fact that students do not want to do their homework makes this difficult:

> I want to give them a wide range of homework. They help students reinforce their learning of the subjects. However, students do not want to study after the lessons are over.

Teachers' Perceptions of Students' Psycho-social Needs

Build Motivation and Trust

Student motivation was identified as an important component of the educational context by three-quarters of the interviewees:

> Sometimes you have to motivate students to participate in the classes and activities, make them feel what they can do.

Building student trust is viewed as an important outcome of group education, something especially needed in the context of distance education. Teachers expect their students to be open to seeking assistance and "not to be afraid of asking questions or making mistakes. More than half of the participants emphasized the significance of developing students' self-confidence and were fully cognizant that their assistance was useful in this process:

> Sometimes students say they can't manage it. In this case, when we support the students, they see what they can achieve.

Social Interaction

According to the responses of the twenty-nine people polled, social interaction is an important goal of group lessons for students. This observation is consistent with the findings of Oliver et al. (2009), as well as those of Campell et al (2019).

> Students can feel lonely during this pandemic when we are all in our homes. We see the lessons as an opportunity for students to communicate with us and other friends and we encourage this.

Teachers stated that it is important to make students feel a sense of belonging and inclusiveness, and especially group activities leave positive impressions on students. At the same time, they stated that this situation is important for the socialization of the students and that the interaction of the students especially with other students will ensure that the teaching is carried out much more effectively.

Teachers’ Perceptions of Students’ Educational Needs

Changing of Students’ Expectation

As technology has improved, students' expectations of the courses have changed. The majority of the teachers interviewed stated that they structured their courses according to the changing expectations of the students:

> We try to use visual and auditory technological tools more in our courses so that students can benefit more from the courses.

Collaboration

Collaboration is a skill which can be developed through group work (Bates & Poole, 2003; Jonassen, 2005). Forty-five of the teachers interviewed stated this as follows:

> Providing students with the opportunity to work as a group is quite useful.

Also, these teachers stated that collaboration and group projects help students learn more effectively by allowing them to interact with one another:

> Our courses provide the opportunity to interact with our students who do not have the opportunity to meet face-to-face during the pandemic. We are also trying to support peer learning by taking this opportunity to encourage students to collaborate and do group work.

Problems Arising in Online Presentation

The interviews aimed to determine the participants' group teaching perceptions. Besides, two areas that are important to meet the stated goals were emphasized: The first of these are online problems, and the second is the possible mismatch between student and teacher expectations regarding the purpose of the course.

Online Issues in Education

Although the participants were not specifically asked about the effect of online presentations, most of them stated this directly or indirectly. There are some problems with online teaching, especially about interaction, which teachers see as a key strategy in facilitating learning or helping students with threshold concepts. According to Paechter and Maiter (2010), although students tried to interact by using online communication methods in online education, they found face-to-face interaction as vital to maintain learning motivation. According to Cornelius (2014), students describe learning in virtual classrooms as an intense or challenging experience in terms of concentration.

The situations that prevent the continuation of interaction are seen as problematic by most of the teachers participating in the study. The interviewed teachers reported that they tried to develop interaction with students in online sessions. However, efforts to improve interaction in the sessions have so far been disappointing for many.

> I put a lot of effort into making students more interactive in online sessions with tools like questions and surveys. However, it is very difficult to get students to talk and to get them to do activities (whiteboard, projection, etc.).

Therefore, although teachers make efforts to develop teaching materials that require feedback from students, students' participation in interaction is at a limited level. It was stated by the participants that the inability to receive feedback from students caused problems both in the communication of teachers with students at an individual level and in determining whether the students understood the subjects.

Interaction during the lessons is seen by teachers as an important factor in helping students improve their self-confidence. The transition to the online education system had no positive impact on interaction between teachers and students. The reason is that online teaching is not as effective as face-to-face teaching.

> I don't think online education is as effective as face-to-face training. The students think that they know what they are doing and can do it together only because they are in the same class.

Some teachers observed it can be helpful to watch online sessions recordings:

> I think recording online lessons is beneficial as it allows students to watch and repeat lessons.

Widespread difficulties for interaction in online education can be encountered, some teachers considering this style of presentation to be beneficial, resulting from increased participation in the learning activities. The variable nature of students' context was stated as a factor causing changes in student expectations by almost all the teachers. Teachers believe that teaching materials and teaching methods have changed with the development of technology and that the expectations of students from the courses have similarly changed. The teachers often stated that students use technological tools more often to meet such expectations. However, because teachers do not yet have enough experience in the use of certain technological tools and distance education, it creates some challenges for them.

The importance of face-to-face education in facilitating independent learning is mentioned by many educators. However, often there are some difficulties in attending face-to-face classes and this can be seen as a disadvantage. Online programs can help achieve stronger participation. Students' ease of access to online activities enables more participation than face-to-face training. Although it has still some problems, Teachers stated that the positive features of online education dominant than the negative features.

Differences between Teacher and Student Expectations from Courses

Another area of interest is the variation between teachers' perceptions of themselves and students' expectations from these teachers. The mismatch between expectations can cause concern in any service-providing organization. According to Byrne et al. (2012), if these expectations are not met in an educational institution, students may fail, withdraw or not participate fully in classes. Most of the teachers interviewed stated students expect more traditional teaching ways in the course instead of more interactive ways. It can be stated that this is because students expect a lecture-style presentation and teachers prefer a more interactive approach. Also, these findings overlap with Stevenson et al.'s (1996) findings. Although the subject area, level, and presentation style are very different, most students expect distance education lessons to be taught like face-to-face lessons.

On the other hand, teachers see interaction as an important key for students to better understand threshold concepts (Price et al., 2010) because this is thought to provide a way to understand and guide improvisation to meet the needs of students. Particularly given the difficulties in online interaction mentioned above, the majority of teachers stated that students’ unwillingness to participate actively in classes posed difficulties in the educational model. Besides, skills that can be developed during training such as collaboration and group work, which are considered important for the workplace by teachers, can be difficult to include or even fail if students are reluctant to embrace them. It is unclear whether this reluctance in participation is due to students' choice of lecture-style presentation, or the inhibition of social presence caused by the online perimeter (Kear et al., 2012). However, lecture style, presentation, focused group work, and well-mediated discussion are valuable for students in face-to-face environments (Yacci, 2000). When the appropriate activities are given, students can participate and value online group work.

The issue of extracurricular evaluation activities is another incompatibility. Almost all of the teachers interviewed stated that they expected students to attend their classes and complete their assignments. Teachers want students to learn the subjects in the courses at a level that will equip them with the targeted skills and competence. However, students expect to learn the subjects at a minimum level, just enough to pass the exams. Teachers, who are experts in their lessons, are aware of the need for students to participate in the lesson intellectually and to expand their learning experience beyond the study materials. When these areas emphasized by teachers were closely examined, it was found that overall these findings were similar to the findings by Campbell et al. (2019), who studied online university STEM tutors.

Conclusion

This study intends to explore the perceptions of secondary school STEM educators and the anticipations of student groups regarding their learning within the distance learning model. Using semi-structured interviews and adopting a qualitative approach, not only teacher perceptions of the objectives of the lessons but also the difficulties they face while teaching was identified. STEM teachers think educational activities are to improve students' knowledge and skills by benefiting basic skills such as teamwork and collaboration. Teachers use their previous training to decide on content (concepts and skills) and to select appropriate learning activities. These interviews revealed two major problems faced by teachers. First of all, there were some difficulties in creating effective interaction in the transition to online education using synchronous systems, creating obstacles in the communication between the teacher and students. Secondly, some discrepancies between teachers' perceptions of educator demands and student expectations were identified.

The challenges above need to be further explored and addressed. Online education cannot be simply delivered by directly copying its face-to-face equivalent, and alternative approaches to teaching should be introduced to make the learning environment more relevant and interesting for the student. Institutional strategies on how students should take on a more active role in education need to be developed. This might help students to find out the role that best works with a group (peers and teacher) in their learning progress and can help better achieve the results expected from group training.

Scientific Ethics Declaration

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

Acknowledgements or Notes

As researchers, we would like to thank all teachers who supported the study with their participation.

References

Akgül, G., & Oran, M. (2021). Views of social studies teachers, of middle school students and student parents about distance education during the pandemic process. *Journal of New Approaches in Education, 3*(2), 15-37.

Bates, T. & Poole, G. (2003). *Effective teaching with technology in higher education: Foundations for success*. San Francisco: Jossey-Bass

Bümen, N. T., Ateş. A., Çakar, E., Ural. G., & Acar, V. (2012). Türkiye bağlaminda öğretmenlerin mesleki gelişimi: Sorunlar ve öneriler. *Milli Eğitim Dergisi, 42*(194), 31-50.

Byrne, M., Flood, B., Hassall, T., Joyce, J., Montano, J. L. A., Gonzalez, J. M. G., & Torna-Germanou, E. (2012). Motivations, expectations, and preparedness for higher education: A study of accounting students in Ireland, the UK, Spain and Greece. *Accounting Forum, 36*, 134–144.

Campbell, A., Gallen, A. M., Jones, M. H., & Walshe, A. (2019). The perceptions of STEM tutors on the role of tutorials in distance learning. *Open Learning: The Journal of Open, Distance and e-Learning, 34*(1), 89-102.

Can, E., (2020). Coronavirüs (Covid-19) pandemisi ve pedagojik yansımaları: Türkiye'de açık ve uzaktan eğitim uygulamaları. *Açıköğretim Uygulamaları ve Araştırmaları Dergisi,* 6(2), 11-53.

Cavanaugh, C. S. (2001). The effectiveness of interactive distance education technologies in K-12 learning: A meta-analysis. *International Journal of Educational Telecommunications, 7*(1), 73-88.

Canpolat, U., & Yıldırım, Y. (2021). Ortaokul öğretmenlerinin COVID-19 salgın sürecinde uzaktan eğitim deneyimlerinin incelenmesi. *Açıköğretim Uygulamaları ve Araştırmaları Dergisi, 7*(1), 74-109.

Charmaz, K. (2002). Qualitative interviewing and grounded theory analysis. Gubrium, J.F. & Holstein, J.A. (Eds.), *Handbook of interview research, context and method*. Thousand Oaks, CA: Sage, p.4, 675,694

Chen, N. S., Ko, H. C., Kinshuk, & Lin, T. (2005). A model for synchronous learning using the Internet. *Innovations in Education and Teaching International, 42*(2), 181–194.

Cohen, L., Manion, L., & Morrison, K. (2001). *Research methods in education* (5th ed.). London:Routledge.

Cornelius, S. (2014). Facilitating in a demanding environment: Experiences of teaching in virtual classrooms using web conferencing. *British Journal of Educational Technology, 45*(2), 260-271.

Cunningham, U. (2014). Teaching the disembodied: Othering and activity systems in a blended synchronous learning situation. *International Review of Research in Open and Distributed Learning, 15*(6), 33-51.

Frankham, J. (2017). Employability and higher education: The follies of the 'Productivity Challenge'in the Teaching Excellence Framework. *Journal of Education Policy, 32*(5), 628-641.

Glaser, B., & Strauss, A. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago, IL: Aldine.

Haresnape, J. M., Aiken, F. J., & Wynn, N. C. (2020). Sharing good practice and encouraging community cohesion online: a programme of tutor-led online events for Open University tutors. *Open Learning: The Journal of Open, Distance and e-Learning*, 1-23.

Jelfs, A., Richardson, J. T. E., & Price, L. (2009). Student and tutor perceptions of effective tutoring in distance education. *Distance Education, 3*0(3), 419–441.

Jonassen, D. H. (2005). *Modeling with technology: Mind tools for conceptual change*. Columbus, OH: Merrill/Prentice-Hall.

Kember, D. (1997). A reconceptualisation of the research into university academics' conceptions of teaching. *Learning and Instruction, 7*(3), 255–275.

King, A. (1993). From sage on the stage to guide on the side. *College Teaching*, *41*(1), 30–35.

Macdonald, J., & Campbell, A. (2012). Demonstrating online teaching in the disciplines.A systematic approach to activity design for online synchronous tuition. *British Journal of Educational Technology, 43*(6), 883–891.

Macdonald, J., & Campbell, A. (2012). Demonstrating online teaching in the disciplines. A systematic approach to activity design for online synchronous tuition. *British Journal of Educational Technology, 43*(6), 883–891.

Oliver, K., Osborne, J., & Brady, K. (2009). What are secondary students' expectations for teachers in virtual school environments?. *Distance Education, 30*(1), 23-45.

Paechter, M., & Maier, B. (2010). Online or face-to-face? Students' experiences and preferences in e-learning. *The Internet and Higher Education*, *13*(4), 292-297.

Pichardo Martínez, M. D. C., García Berbén, A. B., De la Fuente Arias, J., & Justicia Justicia, F. (2007). El estudio de las expectativas en la universidad: análisis de trabajos empíricos y futuras líneas de investigación. *Revista electrónica de investigación educativa*, *9*(1), 1-16.

Punch, K.F. (2011). *Sosyal araştırmalara giriş. Nicel ve nitel yaklaşımlar*. (Z. Etöz, Çev. ed.). Siyasal Kitabevi.

Sander, P., Stevenson, K., King, M., & Coates, D. (2000). University students' expectations of teaching. *Studies in Higher education*, *25*(3), 309-323.

Seferoğlu, S. S. (2004). Öğretmen yeterlilikleri ve mesleki gelişim. *Bilim ve Aklın Aydınlığında Eğitim, 58*, 40-45.

Stevenson, K., Sander, P., & Naylor, P. (1996). Student perceptions of the tutor's role in distance learning. *Open Learning, 11*(1), 22–30.

Strauss, A. & Corbin, J. (1998). *Basics of qualitative research: techniques and procedures for developing grounded theory*. Thousand Oaks, CA: Sage, p. 1, 62, 270-272.

Thorpe, M. (2002). Rethinking learner support: The challenge of collaborative online learning. *Open Learning: The Journal of Open, Distance and e-Learning*, *17*(2), 105-119.

Van der Westhuizen, M. E. (2016). *Reconstructing English studies in South Africa through blended learning* (Doctoral dissertation). Stellenbosch: Stellenbosch University.

Wang, Q., Quek, C. L., & Hu, X. (2017). Designing and improving a blended synchronous learning environment: An educational design research. *The International Review of Research in Open and Distributed Learning, 18*(3).

White, C., Ramirez, R., Smith, J., & Plonowski, L. (2010). Simultaneous delivery of a face-to-face course to on-campus and remote off-campus students. *TechTrends, 54*(4), 34-40.

Wilson, T. (1996). Levels of helping: A framework to assist tutors in providing tutorial support at the level students want and need. *Nurse Education, 16,* 270–273.

Xiao, J. (2012). Tutors' influence on distance language students' learning motivation: voices from learners and tutors. *Distance education, 33*(3), 365-380.

Yacci, M. (2000). Interactivity demystified: A structural definition for distance education and intelligent computer-based instruction. *Educational Technology*, *40*(4), 5-16.

Author Information

M.Said Doğru
Kastamonu University, Kastamonu, Turkey
Contact e-mail: msaid.dogru@yahoo.com
ORCID iD: https://orcid.org/0000-0002-9516-1442

Fatih Yüzbaşıoğlu
Anadolu University, Eskişehir, Turkey
ORCID iD: https://orcid.org/0000-0002-0226-7943

Journal of Education in Science, Environment and Health
Volume 7, Issue 4, 2021
https://doi.org/10.21891/jeseh.994458

Preservice Science Teachers' TPACK Development in a Technology-Enhanced Science Teaching Method Course

Tezcan Kartal, Irem Dilek

Article Info

Article History

Published:
01 October 2021

Received:
08 May 2021

Accepted:
27 October 2021

Keywords
TPACK,
Science education,
Science teaching method course

Abstract

This study investigated preservice elementary science teachers' TPACK development throughout a science teaching method course. The pretest-posttest control group was used in the study. At the end of the study, a self-reported TPACK measure was administered to the experimental (n=26) and control (n=23) groups. The experimental group learned about instructional technologies that can be used in science teaching; prepared technology-based science activities, shared these activities with their peers; planned and taught a mini technology-based lesson, evaluated the lesson, and replanned and retaught the lessons. The results showed that the experimental group had positive gains about how to integrate technologies into science teaching. Participants in the experimental group comprehended that teaching science with technology requires more than technical knowledge and skills and that it is essential to realize the interactions between science, technology, and pedagogy. Besides, the experimental group's TPACK significantly differed from the control group. The implications and suggestions were given based on the results.

Introduction

Technology redesigns the learning environment (McLeod & Richardson, 2013) and only improve learning when used appropriately (ISTE, 2016). Science classrooms are natural environments where technology use will occur, as science depends on technology. Technology should be used to perform actions that are complex or impossible without technology. Technology can help embody science subjects and attract students' attention to science (Rehmat & Bailey, 2014). The widespread use of technology in the schools made it essential to guide teachers about the correct use of technology and effective technology integration (Chen et al., 2009). Teachers play a central role in deciding how to incorporate technologies to facilitate and support student learning (Christensen, 2002). Therefore, teachers are expected to prepare students with 21st-century skills, including using new technologies (Kartal, 2017; Kartal & Tasdemir, 2021; Lambert & Gong, 2010; Niess, 2008), and be knowledgeable and skilled in using various ICT-based approaches in their teaching practice (Inan & Lowther, 2010).

Addressing the importance of technology integration in preservice teacher (PST) education, the International Society for Technology in Education has established ISTE standards for teachers and students (ISTE, 2016; 2017). These standards have become an essential component of the learning process. Given the need for developing technology knowledge of PSTs, teacher preparation programs (TPPs) have begun to incorporate the curriculum focusing on teaching PSTs to integrate technology into their classroom (Lambert & Gong, 2010; Niess, 2005). While stand-alone educational technology courses can help increase PSTs' confidence in using technology (Kleiner et al., 2007), they are sometimes insufficient to encourage PSTs to integrate technology effectively into their teaching practices (Wachira & Keengwe, 2011). Therefore, researchers suggest that technology education should be integrated into the teacher education program to encourage more effective technology integration (Niess, 2005; Tondeur et al., 2012). Niess (2005) suggested that TPPs adopt a multidimensional approach that focuses on developing PSTs' competencies in teaching a specific subject area (mathematics/science) with technology each semester. Educators agree that technology can no longer be considered a separate body of knowledge isolated from pedagogical and content knowledge. Mishra and Koehler (2006) introduced TPACK (technological pedagogical content knowledge) as the technology integrated PCK to define the teacher knowledge needed for effective technology integration.

It may be challenging for researchers to determine which approaches may be effective in helping PSTs develop their technological knowledge and skills for future teaching practices (Goktas et al., 2008). Teachers need more opportunities to teach science as an integrated set of knowledge and understand how technologies help learn science (Bransford et al., 2000; Kartal, 2017). Therefore, developing TPACK within science learning and teaching will support teachers in designing and conducting experimental research for their students (Metz, 2008). PSTs need to have a solid understanding of content areas to integrate technology effectively into their learning and teaching experiences (Mishra & Koehler, 2009) and have productive approaches to use technology in conjunction with practical strategies in the context of pedagogical approaches (Harris & Hofer, 2011). Thus, the conceptual framework of Technological Pedagogical Content Knowledge (TPACK) developed by Mishra and Koehler (2006) is widely used to guide technology integration. In this study, the development of preservice science teachers' knowledge required for technology integration during a method lesson was investigated using the TPACK framework.

Theoretical Framework: TPACK

Shulman (1986) pointed out the appropriate selection and use of technologies to represent the content. Using appropriate technologies, if needed, was a part of the curriculum knowledge. Over the years, researchers have tried to combine technology with Shulman's pedagogical content knowledge (PCK). Many researchers emphasized that technological knowledge should be included in Shulman's PCK notion, and technology should be considered an essential component of PCK (Kartal & Afacan, 2017; Kartal & Çınar, 2018; Koehler & Mishra, 2005; Margerum-Leys & Marx, 2002; Mishra & Koehler, 2006; Niess, 2005). Niess (2005) emphasized the importance of helping PSTs develop a comprehensive understanding of what it means to teach with technology. Niess described this knowledge base as "a technology PCK (TPCK)." Mishra and Koehler (2006) developed the TPACK framework more comprehensively and systematically. They created a visual, conceptual framework showing the teacher knowledge required for technology integration (Figure 1).

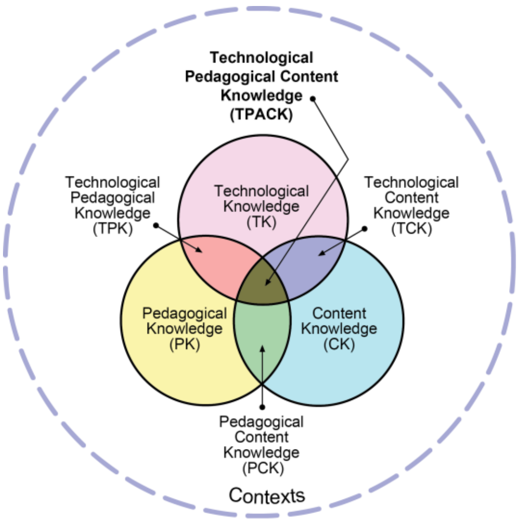


Figure 1. The TPACK framework illustration is adapted from http://tpack.org

It is challenging to assess the relationship between having knowledge of technology and integrating technology (Niess, 2005). Technology should not be considered a separate knowledge or skill to be learned later. TPACK is a valuable theoretical framework for thinking about what teachers should know to integrate technology (Harris & Hofer, 2011; Mishra & Koehler, 2006) and how they can develop this knowledge (Koehler & Mishra, 2008). TPACK helps us understand the difficulties teachers face in integrating technology into the curriculum (Mishra & Koehler, 2006).

The TPACK framework provides a perspective to develop better techniques for exploring and explaining how technology-related professional knowledge occurs in practice (Koehler & Mishra, 2009; Mishra & Koehler, 2006). TPACK framework includes technology knowledge (TK), content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK). The emphasis on integrated knowledge areas (TCK, TPK, PCK, and TPACK) is also essential for defining this framework. TPACK is a synthesized form of information that emerges from TK, PK, and CK interactions. Mishra and Koehler's (2006, 2009) TPACK framework requires knowing and using various new technologies that enable the teaching, representation, and facilitation of knowledge in a particular subject area (Chai et al., 2013; Kartal, 2020; Kartal & Afacan, 2017; Koehler & Mishra, 2009).

Content knowledge is the knowledge about a particular subject matter (e.g., science concepts) (Shulman, 1986). Since the nature of knowledge differs from subject matter to subject matter (e.g., science and mathematics), it is critical for teachers to deeply know the disciplines they teach (Mishra & Koehler, 2006; Shulman, 1986) and to develop CK (Koehler & Mishra, 2008). Teachers should know the content they will teach and how knowledge differs for the various content areas.

Pedagogical knowledge is the teacher's knowledge in creating and facilitating effective teaching and learning environments for students (Koehler & Mishra, 2008). Three types of PK are defined: general pedagogical knowledge, personal pedagogical knowledge, and context-specific pedagogical knowledge (Morine-Dershimer & Kent, 1999). General PK includes knowledge of teaching strategies, teaching models, classroom management, classroom organization, and classroom communication and discourse (Chai et al., 2013; Harris, Mishra, & Koehler, 2009; Hilton, 2016; Mishra & Koehler, 2006; Padmavathi, 2017). Personal PK is concerned with practical experiences and personal beliefs and perceptions (Morine-Dershimer & Kent, 1999). Context-specific pedagogical knowledge is formed by combining both general and personal PK.

Technological knowledge involves the knowledge and skills required to use and master various technological tools (Chai et al., 2013; Harris et al., 2009; Hilton, 2016; Mishra & Koehler, 2006). TK is considered a type of knowledge produced and adapted through new and changing technologies (Harris et al., 2009; Koehler & Mishra, 2008). Teachers who are fluent in information technologies can develop appropriate ways to accomplish a particular task with technology and constantly adapt to technological changes (Bransford et al., 2000; Koehler & Mishra, 2008).

Pedagogical content knowledge is the interaction between pedagogy and content knowledge (Mishra & Koehler, 2006). PCK is a distinctive characteristic between educators and content professionals in specific content areas (Shulman, 1987). For example, scientists may have rich CK but may not have the pedagogical content knowledge necessary to become effective science educators. PCK helps develop instructional applications in content (Koehler & Mishra, 2008; Padmavathi, 2017). For example, a science teacher with strong pedagogical content knowledge guides students to think about how the buoyant force of liquids occurs and the factors that affect this force while knowing how students develop their ideas and what misconceptions they may have.

The component that needs the most scaffolding within the framework of TPACK is *technological content knowledge* (Koehler & Mishra, 2008). This form of knowledge requires knowing and understanding how technology can affect and be used in a subject area (Chai et al., 2013; Harris et al., 2009; Hilton, 2016; Mishra & Koehler, 2006; Padmavathi, 2017). For example, a science teacher needs technological content knowledge to determine which technologies can be used for tasks such as explaining how to measure gravity, comparing the differences between the earth's gravity and the moon's gravity, and observing the absence of gravity.

Technological pedagogical knowledge includes knowing which technologies are compatible with teaching and learning strategies in particular grade levels (Harris et al., 2009) and which technologies best contribute to specific educational contexts (Chai et al., 2013; Mishra & Koehler, 2006). For example, in teaching the buoyancy and effects of fluids, a science teacher needs technological pedagogical knowledge to recognize the pros and cons of using diagrams, animations, or simulations to help students understand the concept.

Technological pedagogical content knowledge is a framework for understanding and defining the knowledge, and skills teachers need for effective pedagogical practice in a technology-supported learning environment (Padmavathi, 2017). PSTs are expected to understand how students can utilize technology to improve their knowledge of the subject matter (Cox & Graham, 2009). Practical experiences with technology should be specific to content areas (Niess, 2005; Schmidt et al., 2009). For example, to help students understand how gravity works, a science teacher with TPACK can use a gravity simulator to make students explore properties that affect gravity (mass and distance) and study the effects of gravity on objects. With the representations of the gravity simulator, the teacher asks students to observe and explain the relationship between the force of gravity and the mass of related objects.

TPACK and TPACK Development in Science Education

PSTs should have the necessary knowledge and skills to integrate technologies into the classroom and use them in a pedagogically appropriate way (McCrory, 2008; Niess et al., 2010). US Department of Education (2017) emphasized that technology-supported professional learning experiences should increase teachers' digital literacy and create learning activities that improve learning, teaching, evaluation, and teaching practices. PSTs' perceptions of teaching and learning stem from their personal experiences about teaching (Richardson-Kemp & Yan, 2003).

Given the importance of developing technology knowledge in teachers, TPPs focused on preparing teachers to use technology in classrooms. Most TPPs typically offer a stand-alone educational technology course to meet specified technology requirements (Lambert & Gong, 2010). These educational technology courses may increase PSTs' confidence in using technology, but they may not be effective in encouraging PSTs to integrate technology effectively into teaching practices (Wachira & Keengwe, 2011). In TPPs, PSTs can develop TPACK by taking educational technology courses, context-specific teaching methods courses, or practicums and engaging with the TPACK knowledge domains during these courses (Hofer & Grandgenett, 2012). Harris and Hofer (2011) stated that after attending the TPACK-focused professional development program, teachers' awareness of curriculum-based learning activities increased with technology integration. Teachers' TPK evolved, their choices of technology-based learning activities were more structured diverse, and their lesson plans became student-centered. They also reported that teachers had raised their quality standards for technology integration, and their decisions for the use of educational technology have become more purposeful.

The educational technology course is essential for prospective teachers' professional development and provides a foundation for technology integration. The developed skills in educational technology courses can be transferred to the teaching method courses. Therefore, it seems necessary to examine how these skills can be developed in TPPs (Kartal & Çınar, 2018; Kleiner et al., 2007). Schmidt et al. (2009) examined how PSTs' TPACK changed after taking an instructional technology course. PSTs had statistically significant gains in all seven TPACK knowledge domains after completing a required technology course, with a large increase in the fields of TK, TCK, and TPACK. Chai, Koh, and Tsai (2010) found significant differences in the TPACK knowledge domains between pretest and post-test results of PSTs who attended an educational technology course.

Maeng, Mulvey, Smetana, and Bell (2013) investigated the development of preservice science teachers' TPACK through technology-enhanced inquiry education. The results showed that the participants perceived the value of the technology and utilized the appropriate technologies to facilitate the inquiry experiences. Lehtinen et al. (2016) investigated the effect of using simulations in science teaching on preservice science teachers' TPACK development. There were statistically significant differences between pre and post-tests in CK, PK, and TPACK knowledge domains. Preservice science teachers' TK was associated with their views on the usefulness of simulation and their tendency to integrate simulations in teaching. Similarly, Habowski and Mouza (2014) stated that a content-specific technology integration course could develop PSTs' understanding to combine technology with science and pedagogy. In addition, the content-centric nature of the lesson encouraged PSTs to think about TCK more often than TPK.

PSTs need to develop strategic thinking that includes planning, organizing, and criticizing specific content, student needs, and specific classroom situations. Method courses provide a natural environment to build the knowledge, skills, and tendencies defined in TPACK (Kartal & Çınar, 2018; Mouza et al., 2017; Niess, 2008). In the study conducted by Mouza and colleagues (2014), PSTs attended the educational technology course, method course, and field experience via an integrated approach. At the end of the study, TPACK increased significantly. In addition, it was found that PSTs' TK, TPK, and TPACK improved in their field experiences. More experiences in teaching technology-related information in classrooms will encourage PSTs' PCK and TPACK development, which will lead to more confidence and more positive attitudes in teaching (Zhan et al., 2013).

Alayyar et al. (2012) used the TPACK framework to prepare preservice science teachers for ICT integration. The results reported an increase in participants' TK, TPK), attitudes towards ICT as a tool for instruction and productivity, and enjoyment of ICT. Kaplon-Schilis and Lyublinskaya (2015) investigated changes in preservice special teachers' TK, PK, CK, and TPACK in a technology-based science and mathematics instruction course. PSTs showed a significant difference in TPACK but did not significantly change PK, TK, and CK during the course. Participants made various progress in their TPACK development, and the average scores of all TPACK components showed that participants progressed from acceptance level to adaptation level.

Kafyulilo et al. (2015) concluded that participating in professional development programs that include designing, teaching, assessment, and redesigning may effectively develop PSTs' knowledge and skills integrate technology into science and mathematics instruction. In the research conducted by Jang (2010), it is addressed that (i) science teachers used interactive boards as a teaching tool to share their CK and express students' understanding, (ii) interactive boards improved the representation repertoire and teaching strategies of science teachers who had difficulties in the traditional classroom, and (iii) the proposed model to integrate interactive boards and peer coaching could improve science teachers' TPACK.

TPACK is a practical conceptual framework for thinking about teachers' knowledge to integrate technology into teaching. Researchers examined PSTs' TPACK development in professional development programs (Chai et al., 2013; Graham et al., 2009; Harris & Hofer, 2011; Kafyulilo et al., 2015), instructional technology (IT) courses (Agyei & Keengwe, 2014; Habowski & Mouza, 2014; Maeng et al., 2013; Mouza et al., 2014, 2017) and teaching method courses (Lehtinen et al., 2016; Maeng et al., 2013; Mouza et al., 2014, 2017; Buss et al., 2018). Using the TPACK framework may be helpful when designing professional experiences for PSTs (Schmidt et al., 2009). The science teaching methods course is a fruitful context for PSTs' TPACK development (Polly et al., 2010). However, more research still needs to investigate preservice science teachers' TPACK development in different contexts (Maeng et al., 2013). This study examined the effect of a science teaching method course that included experiences of learning and teaching science with technology on preservice elementary science teachers' TPACK development within the context of a pretest-posttest control group design. The research questions that guided the study are:

(1) Are there any differences in the pretest scores of the experimental (the science teaching method course that included technology-supported learning and teaching experiences) and the control (the science teaching method course that does not include technology-supported learning and teaching experiences) groups?
(2) Are there any differences between the pretest and post-test scores of the experimental group?
(3) How did the relationships between the experimental participants' TPACK (central component) and other knowledge domains change through the science teaching method course?
(4) Are there any differences between the pretest and post-test scores of the control group?
(5) Are there any differences in the post-test scores of the experimental and the control groups?

Method

Research Design

This study investigated the effect of a science teaching method course enhanced with the experiences related to learning and teaching science with technology on preservice science teachers' TPACK. A pretest-posttest control group design was used (e.g., Kafyulilo et al., 2015; Lehtinen et al., 2016). Two cohorts of the method course were assigned randomly as experimental and control groups. Data were collected simultaneously in both groups (Fraenkel et al., 2012). Table 1 demonstrates the research design.

Table 1. The pretest-posttest control group research design

Groups		Pretest	Treatment	Posttest
Control Group	R_1	O		O
Experimental Group	R_2	O	X	O

R_1, R_2: Random assignment
O: TPACK self-assessment scale (Dependent variable)
X: Technology-enhanced science teaching method course

Participants

Considering the ethical issues, we started the research process by obtaining the necessary official permissions from the university administration where the research was conducted. In addition, further information about the research was given to the preservice teachers who will participate in the research, and voluntariness was necessary to participate in the study. Participants were informed that the data obtained during the research would be used only for the purpose and scope of the research. The research was carried out in the natural setting of the participants. The data obtained during the research were not used to create clues about the participants (name, gender, age, etc.).

Senior preservice science teachers who enrolled in the two cohorts of science teaching method courses in a university located in Central Anatolia were asked to participate voluntarily in the study. The TPP offers a four-year undergraduate education for elementary science teacher education. Until the final year (6 semesters), PSTs took many different CK, PK, pedagogical content knowledge, and TK courses. A TPACK self-assessment scale was administered as a pretest to 54 PSTs at the beginning of the course. To ensure the equivalence of the experimental and control groups' pretest scores in the central component, TPACK, we excluded two PSTs from the experimental group and three PSTs from the control group from the data analysis. The numbers of the females and males in control and experimental groups were given in Table 2.

Table 2. Females and males in the experimental and control groups

Groups	Female	Male	Total
Experimental Group	19	7	26
Control Group	17	6	23
Total	36	13	49

Finally, 49 PSTs ($N_{experimental}$=26, $N_{control}$= 23) participated in the study. Nineteen of the experimental group PSTs and 17 of the control group PSTs were female. The participants ranged in age from 21 to 24 (M = 22.4).

Research Context

In the first four weeks of the course, the experimental group participants were introduced to instructional technologies specific and not specific to science. The instructor (first author) addressed how to integrate various technologies (such as animation, video, digital stories, etc.) into science and the difficulties that can be faced in teaching science with technology, and how to overcome these difficulties. Experimental group PSTs learned about interactive puzzles (eclipse crossword), interactive presentation tools (Prezi), probeware, concept map software (inspiration), PhET (physics education technology), crocodile physics, and interactive physics programs (Kartal, 2017). Then they were grouped into three to four. These groups developed activities related to integrating these technological tools when teaching science and shared their activities with their peers within the course. Teaching how to use various instructional tools in science teaching and allowing the PSTs to develop activities with these tools took four weeks.

Then, PSTs were asked to design a technology-supported mini science lesson (15 minutes) individually and teach this mini-lesson to their peers (microteaching). The lectures of each PST were videotaped. The whole PSTs watched these videos in the class. Then the lessons were evaluated by themselves (self-assessment), the course instructor (expert assessment), and peers (peer assessment). The instructor aimed to help PSTs reflect on their lessons based on the assessments. After the assessment, PSTs had the opportunity to redesign and reteach their lessons. The reteaching try-outs were also video-recorded, but they were not re-evaluated in the classroom environment. The limited time allocated for the course was effective in not making the second assessment. This limited time can be considered as a limitation depending on the number of PSTs. With the technology-supported microteaching, PSTs actively experienced the teaching process. Considering the assessments, they had the opportunity to reflect on how and why various technologies were integrated into science teaching. The PSTs experienced planning a lesson and activity and adapting innovative teaching methods and strategies in this section of the course.

PSTs in the control group did not receive training related to instructional technologies. They were asked to plan and teach a mini-science lesson (15 minutes). The lectures in this group were not video-recorded and were not evaluated. For this reason, the second lecture (reteaching) did not occur in this cohort.

Table 3. Sample items, number of items, and Cronbach' alpha for each TPACK knowledge domain

Construct	Exemplary Item	Number of Items	Cronbach's α
PK	I think I can determine teaching methods according to students' levels.	15	.965
TK	I think I do not have trouble using technology.	11	.932
CK	I think I know conceptions, rules, and generalizations in my content area.	8	.924
TCK	I think I can use technology to help abstract concepts be learned.	5	.963
TPK	I think I know how technology affects teaching and learning.	10	.936
PCK	I think I am familiar with students' misconceptions about a specific topic.	11	.944
TPACK	I think I can decide which technologies positively affect teaching and learning.	7	.925

Data Collection Tool

It is common to use questionnaires in examining TPACK development (Schmidt et al., 2009). In this context, TPACK Self-Assessment Scale, TPACK-SAS, was used to investigate the TPACK development of preservice science teachers. TPACK-SAS was developed by Kartal et al. (2016) and included seven factors and 67 items. The scale items are 7-point Likert ranging from "strongly agree" to "strongly disagree" to increase the reliability of the measurement, as suggested by Thorndike (2005). The researchers used the thinking aloud strategy with two preservice science teachers who were not participants to increase the validity of the scale items. Sample items, number of items, and Cronbach's alpha values for each subdimension of the scale are given in Table 3.

Data Analysis

Before analyzing data from the TPACK-SAS, it was examined whether the data had a normal distribution. Kolmogorov-Smirnov normality test was performed, and the Skewness-Kurtosis values were calculated. Kolmogorov-Smirnov value was not statistically significant (p>.05), and skewness-kurtosis values were calculated as .516 and -.407, respectively. If the Kolmogorov-Smirnov test results are not significant for data with a sample size of more than 50, it shows that the data has a normal distribution. According to Tabachnick and Fidel (2019), kurtosis-skewness values should be between +1.5 and -1.5 for the normal distribution. According to the results of the normality tests and skewness-kurtosis values, it can be said that the data set has a normal distribution.

SPSS was used in the analysis of the data in this study. Before analyzing the data, the data were examined for missing data. The t-tests were used for dependent and independent groups to compare the mean scores within and between groups. The effect size was calculated to determine the level of the difference between groups or variables. Effect size describes the magnitude of the observed effects regardless of the possible misleading impact of the sample size. The effect sizes for the TPACK-SAS results were calculated using Cohen's d. The effect sizes of .2, .5, and .8 were interpreted as a *small*, *medium*, and *large* effect sizes, respectively (Cohen, 1988). Pearson's correlation analysis was also used to examine the relationships between the central TPACK and other knowledge domains.

Results

Results Related to Pretest

The equivalence of the experimental and control groups was examined by comparing preservice science teachers' pretest scores in the central TPACK component. The results are given in Table 4.

Table 4. T-test results regarding the pretest mean scores of the experimental and control groups

Scale	Administration	Group	N	M	Sd	t	p
TPACK (Central Component)	Presurvey	Experimental Group	26	5.385	.650	.019	.985
		Control Group	23	5.389	.660		

Table 4 demonstrates that the control group (M=5.389) had higher mean scores than the experimental group (M=5.385) in the pretest. However, the difference between mean scores ($M_{control}$-$M_{experimental}$=.004) is not statistically significant (t=.019, p>.05). It is possible to say that there is no difference between the experimental and control groups regarding the central TPACK component.

Results Related to Pretest and Post-test of The Experimental Group

The experimental group's mean scores in TPACK knowledge domains were compared, and the results were given in Table 5. Preservice science teachers showed statistically significant gains in their PK (t=1.969, p<.05; d=.547), CK (t=2.723, p<.05, d=.770), TPK (t=2.556, p<.05, d=.565) and TPACK (t=4.071, p<.05; d=1.151). The largest gain was in TPACK. The experiences of learning and teaching science with technology may have improved participants' CK, PK, knowledge of pedagogy due to selected technology, and knowledge of pedagogy, technology, and content. The gains in PK, CK, and TPK had medium effect sizes. Additionally, participants rated themselves higher in the post-test than the pretest in TK, TPK, and PCK, but these gains were not statistically significant.

Table 5. t-test results regarding the pretest and post-test mean scores of the experimental group

Knowledge Domains	Group	Administration	N	M	Sd	t	p	Cohen 's d
PK	Experimental Group	Pretest	26	5.548	.521	1.969	.045*	.547
		Post Test	26	5.851	.584			
TK	Experimental Group	Pretest	26	4.874	1.151	.553	.583	-
		Post Test	26	5.038	.985			
CK	Experimental Group	Pretest	26	4.447	1.263	2.723	.009*	.770
		Post Test	26	5.208	.661			
TCK	Experimental Group	Pretest	26	5.553	.833	1.399	.168	-
		Post Test	26	5.838	.617			
TPK	Experimental Group	Pretest	26	5.400	.748	2.556	.014*	.565
		Post Test	26	5.859	.528			
PCK	Experimental Group	Pretest	26	5.807	.793	.278	.782	-
		Post Test	26	5.867	.749			
TPACK	Experimental Group	Pretest	26	5.461	.598	4.071	.000*	1.151
		Post Test	26	6.082	.497			

The change in relationships between the central TPACK component and other knowledge domains throughout the study was given in Figure 2.

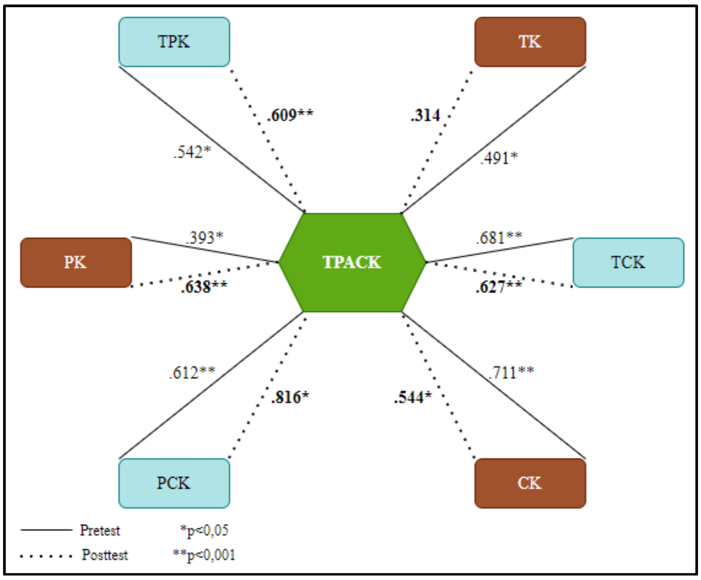


Figure 2. Correlation coefficients between the central TPACK component and other knowledge domains at the beginning and the end of the course

PSTs' TPACK was significantly correlated with their PK (r=.393, p<.05), TK (r=.491, p<.05), CK (r=.711, p<.001), TPK (r=.542, p<.05), TCK (r=.681, p<.001), and PCK (r=.612, p<.001) at the beginning of the course; and with their PK (r=.638, p<.001), CK (r=.544, p<.05), TPK (r=.609, p<.001), TCK (r=.627, p<.001), and PCK (r=.816, p<.001) at the end of the course. The post-test results demonstrated that TPACK was not significantly correlated with TK (r=.314, p>.05). The correlations between the central TPACK component and PK, TPK, and PCK increased significantly at the end of the course. The significant gains in PK may lead to strengthen the correlation between these constructs. In addition, the correlation between content-specific and technology-specific PK and TPACK increased. The development of these knowledge domains (PK, TPK, and PCK) are expected to contribute to the development of the TPACK. However, it is seen that there is a strong correlation, although the correlation coefficient between TPACK and CK and TCK decreased.

Results Related to Pretest and Post-test of The Control Group

The control group's mean scores in TPACK knowledge domains were compared, and the results were given in Table 6.

Table 6. t-test results regarding the pretest and post-test mean scores of the control group

Knowledge Domains	Group	Administration	N	M	Sd	t	p	Cohen's d
PK	Control Group	Pretest	23	5.736	.764	-.862	.393	-
		Post Test	23	5.573	.481			
TK	Control Group	Pretest	23	4.924	1.159	1.376	.176	-
		Post Test	23	5.339	.865			
CK	Control Group	Pretest	23	4.552	1.053	1.603	.116	-
		Post Test	23	5.005	.968			
TCK	Control Group	Pretest	23	5.652	.615	1.436	.158	-
		Post Test	23	5.904	.574			
TPK	Control Group	Pretest	23	5487	.809	2.579	.013	.760
		Post Test	23	6.000	.505			
PCK	Control Group	Pretest	23	5.691	.920	1.175	.246	-
		Post Test	23	5.968	.655			
TPACK	Control Group	Pretest	23	5.559	.853	.488	.628	-
		Post Test	23	5.670	.692			

PSTs in the control group had higher scores in the post-test than in the pretest in knowledge domains except for PK. For PK, participants' pretest scores were higher than their post-test scores. The difference between mean scores of TPK is statistically significant (t=2.579, p<.05; d=.760) with a *medium* effect size. These results may imply that the control group perceived themselves as more knowledgeable in technology-related PK at the end of the course.

Results Related to Post-survey

The independent t-test results regarding post-test mean scores of the experimental and control groups were given in Table 7.

Table 7. t-test results regarding the post-test mean scores of the experimental and control groups

Knowledge Domains	Group	Administration	N	M	Sd	t	p	Cohen's d
PK	Post Test	Experimental Group	26	5.851	.584	1.175	.046*	.519
		Control Group	23	5.573	.481			
TK	Post Test	Experimental Group	26	5.038	.985	1.131	.264	-
		Control Group	23	5.339	.865			
CK	Post Test	Experimental Group	26	5.208	.661	.864	.392	-
		Control Group	23	5.005	.968			
TCK	Post Test	Experimental Group	26	5.838	.617	.385	.702	-
		Control Group	23	5.904	.574			
TPK	Post Test	Experimental Group	26	5.859	.528	.947	.349	-
		Control Group	23	6.000	.505			
PCK	Post Test	Experimental Group	26	5.867	.749	.500	.619	-
		Control Group	23	5.968	.655			
TPACK	Post Test	Experimental Group	26	6.082	.497	2.412	.020*	.683
		Control Group	23	5.670	.692			

Table 7 demonstrates that the experimental group's PK (t=1.175, p<.05, d=.519) and TPACK (t=2.412, p<.05; d=.683) significantly differed from the control group in the post-test. These significant differences had *medium* effect sizes. Technology-based science learning and teaching experiences positively affected preservice science teachers' PK and TPACK.

Results and Discussion

This study investigated the effect of a technology-enhanced science teaching method course on preservice elementary science teachers' TPACK, using a pretest-posttest control group design. A self-reported measure, TPACK-SAS, was used at the beginning and end of the course to allow PSTs to rate their competencies in teaching with technology. The experimental group included 26 participants, and the control group had 23. The pretest and post-test mean scores of the experimental group are given in Figure 3. The experimental group had significantly positive gains in PK, CK, TPK, and TPACK. The largest effect of the method course was in the central TPACK component.

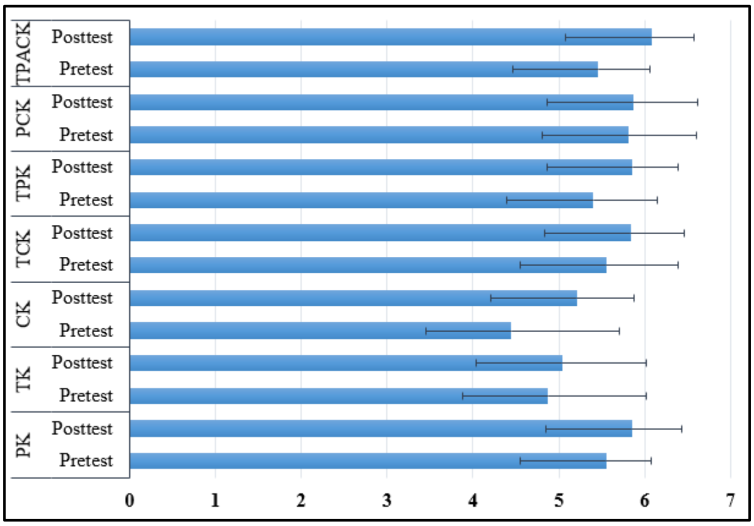


Figure 3. The pre-and-posttest mean scores of the experimental group

PSTs are expected to acquire PK related to teaching strategies, teaching models, classroom management, organization, and communication and discourse until their final year. The teaching experiences in the course may allow PSTs to transfer their theoretical knowledge into practice and lead to an improvement in their PK. This result is similar to the results of many studies (Chai et al., 2010, 2013; Lehtinen et al., 2016; Morine-Dershimer & Kent, 1999; Pamuk, 2012). Morine-Dershimer and Kent (1999) stated that as PSTs gained experience designing lessons and teaching practices, they would become more comfortable in pedagogy.

The positive gains in the CK of the experimental group may be because of PSTs' experiences related to planning and teaching a mini science lesson. PSTs may have tried to explain and exemplify the concepts and principles related to the science concepts they would teach. This may have contributed to the development of their CK. In the study conducted by Lehtinen et al. (2016), science teachers integrated interactive whiteboard resources such as e-books, animation, and the internet into teaching and learning. They had positive changes in their CK.

The method course that included learning and teaching science with technology positively affected the experimental group's TPK. This result may imply that the course promoted PSTs' understanding of the interactions and associations between technology and pedagogy. Figg and Jaipal (2009) stated that teachers need TPK to integrate technology successfully. They expressed that TPK plays a crucial role in planning and implementing successfully, and the lack of this integrated knowledge may negatively affect teaching practices. The literature reported similar (Alayyar et al., 2012; Jaipal & Figg, 2010; Koh & Divaharan, 2011) and different (Mouza et al., 2014; Pamuk, 2012; Polly et al., 2010) results. The introduction of technologies and the discussions about integrating instructional technologies into science teaching may have guided PSTs to consider how technology changes specific pedagogies and vice versa. Additionally, planning a science lesson two times may have improved their TPK.

The most significant gain occurred in the central TPACK component. It is possible to say that the method course, including technology-enhanced science learning and teaching activities, is an effective means of improving PSTs' TPACK. The course helped PSTs perceive themselves as increasing the knowledge and competencies needed for effective technology integration. The developing TPACK has been seen in many research (Agyei & Voogt, 2012; Chien, Chang, Yeh, & Chang, 2012; Koh & Divaharan, 2011; Zhan et al., 2013). Teaching experience effectively improves PCK and TPACK (Agyei & Voogt, 2012; Zhan et al., 2013). However, it is worth noting that the PCK of participants did not improve significantly, even though they experienced planning and teaching two times. This may be because the participants rated themselves most competent in PCK in the pretest. Similarly, Kafyulilo and colleagues (2015) reported that their professional development program did not improve participants' PCK significantly since the participants were relatively high in PCK at the start of the program.

The absence of significant improvements in PSTs' TK and TCK needs to be considered since the first four weeks of the course included introducing instructional technologies and allowing participants to prepare technology-enhanced science activities. It may be challenging to develop TCK (Chai et al., 2013). It is needed more than introducing specific technologies; PSTs need to explore and use more technologies specific to science. Additionally, PSTs may not have perceived the instructional technologies as tools for developing their technological competencies. The duration allocated to using these technologies (four weeks) may be insufficient to develop TK and TCK.

The study revealed the relationships between the central TPACK component and other knowledge domains at the beginning and end of the course. The results showed that the integrated knowledge domains (TPK, TCK, and PCK) were significantly correlated to the central TPACK component at the beginning and end of the course. The correlation coefficients between the integrated knowledge domains and the central TPACK component increased at the end of the study. These results may imply that the PSTs had an integrative view that assumed that teaching with technology requires a comprehensive understanding of relationships between technology, pedagogy, and content (Agyei & Keengwe, 2014; Koehler & Mishra 2009; Shin, Koehler, Mishra, Schmidt, Baran, & Thompson, 2009). The increase of the coefficients implied that the course supported PSTs' integrated TPACK understanding. Similar results include significant relationships between knowledge domains (Lin, Tsai, Chai, & Lee, 2013) and the strengthening relationships between TPACK and TCK, TPK, and PCK (Shin et al., 2009).

Additionally, TPACK was correlated significantly to TK at the beginning of the study but not correlated at the end of the study. PSTs perceived that having TK and skills is not the same as teaching science with technology. This result underpins the assertion that TK is not enough for effective technology integration (Koh & Divaharan, 2011; Mishra & Koehler, 2006). This result is promising as PSTs realized that teaching science with technology requires more than technical knowledge and skills.

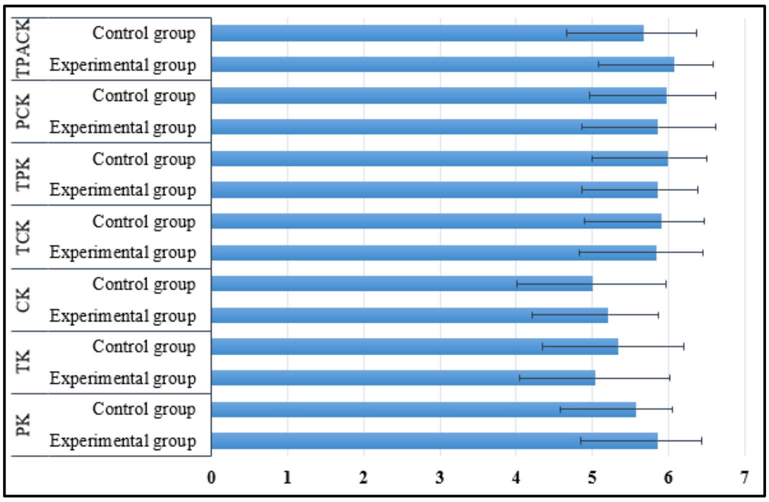


Figure 4. Mean scores of the experimental and control groups in the post-test

This research also compared the groups' mean scores at the end of the course (Figure 4). PSTs in the experimental group rated themselves as more competent than PSTs in the control group in PK and TPACK. The distinguishing characteristics of the intervention in the experimental group were introducing instructional technologies that can be used in science teaching, allowing PSTs to prepare science activities with these technologies, sharing their activities with peers, and engaging in the cycle of teaching-evaluating-reteaching. It is possible to say that incorporating these strategies into teaching method courses promotes preparing PSTs equipped with the knowledge they need to integrate technology effectively.

Recommendations

This study revealed that a science teaching method course incorporating experiences of learning and teaching science with technology developed participants' PK, CK, TPK, and TPACK, promoted PSTs' integrative view of TPACK, and guided PSTs to realize the interactive and dynamic relationships among technology, pedagogy, and science. However, there are some limitations. This study used a self-reported measure that may reveal crucial findings. It is worth expressing that these measures may not reflect participants' actual teaching practices (Jaipal & Figg, 2010). Further research may use various data collection tools (such as observation, interview, lesson plans, and artifacts) and self-reported measures to understand better how PSTs will teach science concepts with technology.

This study took one semester and was conducted in a science teaching method course. The duration allocated for introducing instructional technologies to teach science with technology seems insufficient in developing PSTs' TK and TCK. The longitudinal studies investigating TPACK development within science-specific technology courses, science teaching method courses, and student teaching may help researchers deepen their understanding of PSTs' TPACK development.

Scientific Ethics Declaration

The authors declare that the scientific, ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

References

Agyei, D. D., & Keengwe, J. (2014). Using technology pedagogical content knowledge development to enhance learning outcomes. *Education and Information Technologies*, *19*(1), 155-171.

Agyei, D., & Voogt, J. (2012). Preservice teachers' competencies for technology integration: Insights from a mathematics-specific instructional technology course. In P. Resta (Ed.), *Proceedings of SITE 2012-Society for Information Technology & Teacher Education International Conference* (pp. 1094–1099). Austin, Texas, USA: Association for the Advancement of Computing in Education (AACE).

Alayyar, G. M., Fisser, P., & Voogt, J. (2012). Developing technological pedagogical content knowledge in preservice science teachers: Support from blended learning. *Australasian journal of educational technology*, *28*(8), 1298-1316.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). Technology to Support Learning (Eds). *How people learn: Brain, mind, experience, and school* (Exp. Ed.). Washington, DC: National Academy Press.

Buss, R. R., Foulger, T. S., Wetzel, K., & Lindsey, L. (2018). Preparing teachers to integrate technology into K–12 instruction II: Examining the effects of technology-infused methods courses and student teaching. *Journal of Digital Learning in Teacher Education*, *34*(3), 134-150.

Chai, C. S., Koh, J. H. L., & Tsai, C. (2010). Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK). *Educational Technology & Society, 13*(4), 63-67.

Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2013). A review of technological pedagogical content knowledge. *Journal of Educational Technology & Society*, *16*(2), 31-51.

Chen, F., Looi, C., & Chen, W. (2009). Integrating technology in the classroom: A visual conceptualization of teachers' knowledge, goals and beliefs. *Journal of Computer Assisted Learning*, *25*(5), 470-488.

Chien, Y. T., Chang, C. Y., Yeh, T. K. & Chang, K. E. (2012). Engaging preservice science teachers to act as active designers of technology integration: A MAGDAIRE framework. *Teaching and Teacher Education, 28*(4), 578-588.

Christensen, R. (2002). Effect of technology integration education on the attitudes of teachers and students. *Journal of Research on Technology in Education, 34* (4), 411-433.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd Ed.). Hillsdale, NJ: Erlbaum.

Cox, S., & Graham C. R. (2009). Diagramming TPACK in practice: using and elaborated model of the TPACK framework to analyze and depict teacher knowledge. *TechTrends, 53*(5), 60-69.

Figg, C., & Jaipal, K. (2009). Unpacking TPACK: TPK characteristics supporting successful implementation. In I. Gibson, R. Weber, K. McFerrin, R. Carlsen & D. Willis (Eds.), *Proceedings of SITE 2009--Society for Information Technology & Teacher Education International Conference* (pp. 4069-4073). Charleston, SC, USA: Association for the Advancement of Computing in Education (AACE). Retrieved from https://www.learntechlib.org/primary/p/31295/

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to Design and Evaluate Research in Education* (8th Ed.). McGraw–Hill Companies: New York, NY.

Goktas, Y., Yıldırım, Z., & Yıldırım, S. (2008). A review of ICT related courses in preservice teacher education programs. *Asia Pacific Education Review*, *9*(2), 168-179.

Graham, C., Burgoyne, N., Cantrell, P., Smith, L., Clair, L., & Harris, R. (2009). TPACK development in science teaching: Measuring the TPACK confidence of in-service science teachers. *TechTrends, 53*(5), 70-79.

Habowski, T., & Mouza, C. (2014). Preservice teachers' development of technological pedagogical content knowledge (TPACK) in the context of a secondary science teacher education program. *Journal of Technology & Teacher Education, 22*(4), 471-495.

Harris, J. B., & Hofer, M. J. (2011). Technological pedagogical content knowledge (TPACK) in action: A descriptive study of secondary teachers' curriculum-based, technology-related instructional planning. *Journal of Research on Technology in Education, 43*(3), 211-229.

Harris, J. B., Mishra, P., & Koehler, M. (2009). Teachers' technological pedagogical content knowledge: Curriculum-based technology integration reframed. *Journal of Research on Technology in Education, 41*(4), 393-416.

Hilton, J. T. (2016). A case study of the application of SAMR and TPACK for reflection on technology integration into two social studies classrooms. *The Social Studies*, *107*(2), 68-73.

Hofer, M., & Grandgenett, N. (2012). TPACK development in teacher education: A longitudinal study of preservice teachers in a secondary MA Ed. program. *Journal of Research on Technology in Education*, *45*(1), 83-106.

Inan, F. A., & Lowther, D. (2010). Laptops in the K-12 classrooms: Exploring factors impacting instructional use. *Computers & Education*, *55*(3), 937–944.

International Society for Technology in Education [ISTE]. (2016). *National educational technology standards for students: Connecting curriculum and technology.* Eugene, OR: Author.

International Society for Technology in Education [ISTE]. (2017). *ISTE Standards for Educators: A guide for teachers and other professionals.* Retrieved from https://www.iste.org/standards/for-educators

Jaipal, K., & Figg, C. (2010). Unpacking the "Total PACKage": Emergent TPACK characteristics from a study of preservice teachers teaching with technology. *Journal of Technology and Teacher Education*, *18*(3), 415-441.

Jang, S. J. (2010). Integrating the interactive whiteboard and peer coaching to develop the TPACK of secondary science teachers. *Computers & Education*, *55*(4), 1744-1751.

Kafyulilo, A., Fisser, P., Pieters, J., & Voogt, J. (2015). ICT use in science and mathematics teacher education in Tanzania: Developing technological pedagogical content knowledge. *Australasian Journal of Educational Technology*, *31*(4), 381-399.

Kaplon-Schilis, A., & Lyublinskaya, I. (2015). Exploring changes in technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK) and TPACK of pre-service, special education teachers taking technology-based pedagogical course. In D. Rutledge & D. Slykhuis (Eds.), *Proceedings of SITE 2015-Society for Information Technology & Teacher Education International Conference* (pp. 3296-3303). Las Vegas, NV, United States: Association for the Advancement of Computing in Education (AACE). Retrieved from https://www.learntechlib.org/primary/p/150456/

Kartal, B. (2020). Teknoloji temelli öğrenme-öğretme yaklaşımı: Teknolojik pedagojik alan bilgisi. G. Ekici, (Ed.), *Etkinlik Örnekleriyle Güncel Öğrenme-Öğretme Yaklaşımları-IV* (s. 353-403). Ankara: Pegem Akademi.

Kartal, B., & Çınar, C. (2018). Examining preservice mathematics teachers' beliefs of TPACK during a method course and field experience. *Malaysian Online Journal of Educational Technology*, *6*(3), 11-37.

Kartal, B., & Taşdemir, A. (2021). Preservice teachers' attitudes towards STEM: Differences based on multiple variables and the relationship with academic achievement. *International Journal of Technology in Education (IJTE)*, *4*(2), 200-228.

Kartal, T. (2017). Fen Eğitiminde Teknoloji Entegrasyonu. M. P. Demirci Güler, (Ed.), *Fen Bilimleri Öğretimi: Yaklaşımlar ve Kazanımlar Doğrultusunda Uygulama Örnekleri* (s. 165-199). Ankara: Pegem Akademi.

Kartal, T., & Afacan, Ö. (2017). Examining Turkish pre-service science teachers' technological pedagogical content knowledge (TPACK) based on demographic variables. *Turkish Journal of Science Education, 14*(1), 1-22.

Kartal, T., Kartal, B., & Uluay, G. (2016). Technological pedagogical content knowledge self-assessment scale (TPACK-SAS) for preservice teachers: Development, validity and reliability. *International Journal of Eurasia Social Sciences*, *7*(23), 1-36.

Kleiner, B., Thomas, N., & Lewis, L. (2007). Educational Technology in Teacher Education Programs for Initial Licensure (NCES 2008–040). *National Center for Education Statistics, Institute of Education Sciences, US Department of Education.* Washington, DC.

Koehler, M. J., & Mishra, P. (2005). What happens when teachers design educational technology? The development of Technological Pedagogical Content Knowledge. *Journal of Educational Computing Research. 32*(2), 131-152.

Koehler, M., & Mishra, P. (2008). Introducing TPACK. In AACTE Committee on Innovation and Technology (Eds.). *Handbook of technological pedagogical content knowledge for educators* (pp. 3-29). New York, NY: Routledge.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)?. *Contemporary Issues in Technology and Teacher Education*, *9*(1), 60-70.

Koh, J. H., & Divaharan, H. (2011). Developing preservice teachers' technology integration expertise through the TPACK-developing instructional model. *Journal of Educational Computing Research*, *44*(1), 35-58.

Lambert, J., & Gong, Y. (2010). 21st century paradigms for preservice teacher technology preparation. *Computers in the Schools*, *27*(1), 54-70.

Lehtinen, A., Nieminen, P., & Viiri, J. (2016). Preservice teachers' TPACK beliefs and attitudes toward simulations. *Contemporary Issues in Technology and Teacher Education*, *16*(2), 151-171.

Lin, T. C., Tsai, C. C., Chai, C. S., & Lee, M. H. (2013). Identifying science teachers' perceptions of technological pedagogical and content knowledge (TPACK). *Journal of Science Education and Technology*, *22*(3), 325-336.

Maeng, J. L., Mulvey, B. K., Smetana, L. K., & Bell, R. L. (2013). Preservice teachers' TPACK: Using technology to support inquiry instruction. *Journal of Science Education and Technology*, *22*(6), 838-857.

Margerum-Leys, J., & Marx, R. (2002). Teacher knowledge of educational technology: A study of student teacher/mentor teacher pairs. *Journal of Educational Computing Research*, *26*(4), 427-462.

McCrory, R. (2008). Science, technology, and teaching: The topic-specific challenges of TPCK in science. In M. C. Herring, M. J. Koehler, & P. Mishra (Eds). *Handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 193-206). AACTE Committee on Innovation and Technology. New York: Routledge for the American Association of Colleges for Teacher Education.

McLeod, S., & Richardson, J. (2013). Supporting effective technology integration and implementation. In M. Militello, & J. I. Friend (Eds.), *Principal 2.0: Technology and Educational Leadership* (pp. 249–272). Charlotte, NC: Information Age Publishing.

Metz, K. E. (2009). Elementary school teachers as "targets and agents of change": Teachers' learning in interaction with reform science curriculum. *Science Education, 93*(5), 915-954.

Mishra, P., & Koehler, M. (2006). Technological pedagogical content knowledge: A framework for integrating technology in teacher knowledge. *Teacher College Record, 108*(6), 1017-1054.

Mishra, P., & Koehler, M. (2009). Too cool for school? No way! Using the TPACK framework: You can have your hot tools and teach them, too. *Learning & Leading with Technology, 36*(7), 14-18.

Morine-Dershimer, G., & Kent, T. (1999). The Complex Nature and Sources of Teachers' Pedagogical Knowledge. In J. Gess-Newsome, & N. G. Lederman (Eds). *Examining Pedagogical Content Knowledge: The Construct and Its Implications for Science Education.* New York: Kluwer Academic Publishers.

Mouza, C., Karchmer-Klein, R., Nandakumar, R., Ozden, S. Y., & Hu, L. (2014). Investigating the impact of an integrated approach to the development of preservice teachers' technological pedagogical content knowledge (TPACK). *Computers & Education*, *71*, 206-221.

Mouza, C., Nandakumar, R., Yilmaz Ozden, S., & Karchmer-Klein, R. (2017). A longitudinal examination of preservice teachers' technological pedagogical content knowledge in the context of undergraduate teacher education. *Action in Teacher Education, 39*(2), 153-171.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, *21*(5), 509-523.

Niess, M. L. (2008). Guiding preservice teachers in developing TPCK. In M. C. Herring, M. J. Koehler, & P. Mishra (Eds). *Handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 223-250). AACTE Committee on Innovation and Technology. New York: Routledge for the American Association of Colleges for Teacher Education.

Niess, M. L., Van Zee, E. H., & Gillow-Wiles, H. (2010). Knowledge growth in teaching mathematics/science with spreadsheets: Moving PCK to TPACK through online professional development. *Journal of Digital Learning in Teacher Education, 27*(2), 42-52.

Padmavathi, M. (2017). Preparing teachers for technology based teaching-learning using TPACK. *İ-managers Journal of School Educational Technology, 12*(3), 1-10.

Pamuk, S. (2012). Understanding preservice teachers' technology use through TPACK framework. *Journal of Computer Assisted Learning*, *28*(5), 425-439.

Polly, D., Mims, C., Shepherd, C., & Inan, F. (2010). Evidence of impact: Transforming teacher education with preparing tomorrow's teachers to teach with technology (PT3) grants. *Teaching and Teacher Education 26*(4) 863-870.

Rehmat, A. P., & Bailey, J. M. (2014). Technology integration in a science classroom: Preservice teachers' perceptions. *Journal of Science Education and Technology*, *23*(6), 744-755.

Richardson-Kemp, C., & Yan, W. (2003). Urban school teachers' self-efficacy beliefs and practices, innovation practices, and related factors in integrating technology. In *Society for Information Technology & Teacher Education International Conference* (pp. 1073-1076). Chesapeake, VA: Association for the Advancement of Computing in Education.

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK) the development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education*, *42*(2), 123-149.

Shin, T., Koehler, M., Mishra, P., Schmidt, D., Baran, E., & Thompson, A. (2009). Changing technological pedagogical content knowledge (TPACK) through course experiences. In C. Crawford et al. (Eds.), *Proceedings of Society for Information Technology and Teacher Education International Conference* (pp. 4152-4159). Chesapeake, VA: AACE.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1-23.

Tabachnick, B. G., & Fidel, L. S. (2019). *Using multivariate statistics* (7th Ed.). Boston: Pearson.

Thorndike, R. M. (2005). *Measurement and evaluation in psychology and education.* Upper Saddle River, NJ: Pearson Prentice Hall.

Tondeur, J., van Braak, J., Sang, G., Voogt, J., Fisser, P., & Ottenbreit-Leftwich, A. (2012). Preparing preservice teachers to integrate technology in education: A synthesis of qualitative evidence. *Computers & Education*, *59*(1), 134-144.

U.S. Department of Education, Office of Educational Technology. (2017). *Reimagining the role of technology in education: 2017 national education technology plan update.* Retrieved from https://tech.ed.gov/files/2017/01/NETP17.pdf

Wachira, P., & Keengwe, J. (2011). Technology integration barriers: Urban school mathematics teachers' perspectives. *Journal of Science Education and Technology*, *20*(1), 17-25.

Zhan, Y., Quan, J., & Ren, Y. (2013). An empirical study on the technological pedagogical content knowledge development of preservice mathematics teachers in China. *International Journal of Social Media and Interactive Learning Environments*, *1*(2), 199-212.

Author(s) Information

Tezcan Kartal
Kırşehir Ahi Evran University
Department of Science Education,
Kırsehir, Turkey
Contact e-mail: *tkartal@ahievran.edu.tr*
ORCID ID: https://orcid.org/0000-0001-7609-3555

İrem Dilek
Kırşehir Ahi Evran University
Department of Science Education,
Kırsehir, Turkey
ORCID ID: https://orcid.org/0000-0002-5177-9291

Journal of Education in Science, Environment and Health
Volume 7, Issue 4, 2021 https://doi.org/10.21891/jeseh.991910

The Effect of Free Time Management Skills upon Smartphone Addiction Risk in University Students

Deniz Mertkan Gezgin, Can Mihci, Sinem Gedik

Article Info

Article History

Published:
01 October 2021

Received:
17 January 2021

Accepted:
01 June 2021

Keywords

Free time management
Smartphone addiction
University students
Mobile technologies

Abstract

The purpose of this study is to investigate the effect of free time management skills upon smartphone addiction risk in university students. The study follows a relational screening model of research and makes use of descriptive analyses alongside correlation and stepwise regression statistical methods. The study group consists of 591 university students. A glance at the findings indicate that the overall smartphone addiction risk in the study group is relatively low and that a statistically significant yet weak and negative relationship exists between smartphone addiction risk and free time management skills. Three out of the four sub-dimensions of free time management scale; namely "scheduling", "leisure attitude" and "goal setting" were found to be have statistically significant correlations with smartphone addiction risk at moderate, weak and weak levels respectively. Lastly, a stepwise regression test has shown that the "scheduling" sub-dimension alone is a significant predictor of smartphone addiction risk, explaining 15.2% of variance in scores. In conclusion, these findings may be interpreted as the possession of higher free time management skill in university students is associated with lower risk of smartphone addiction. The basis of this phenomenon may be inclination of some students to prefer spending all their free time using their smartphones, due to lack of management skills. The results have been further discussed further under the light of associated findings in the academic literature and implications for future research have been made.

Introduction

Smartphones are devices that carry similar functionality with and yet display much higher capabilities of information processing and connectivity than regular mobile phones. (Ada & Tatlı, 2012). Smartphones have undeniably dominated human lives in beginning of the 21st century, opening the doors to many possibilities in the lives of individuals. However, as more and more people start to rely on smartphones for fulfilling all their daily life needs, cases of overuse have also become commonplace. Some recent entries in academic literature are prone to classify extreme cases of smartphone reliance and overuse as a form of addiction and inspect this phenomenon from psychological, sociological, cultural, economic and pedagogic perspectives (Bal & Balcı, 2020).

Smartphone addiction is defined as a non-chemical impulse-control disorder similar to pathological gambling (Griffiths, 2005; Park & Lee, 2011). Smartphone addiction also consists of common addiction components such as salience, tolerance, mood modification, conflict, withdrawal and relapse (Griffiths, 2005). The combination of these results in a negative impact upon the life standard and quality of an individual. Although numerous studies have been focusing on the concept of smartphone addiction in the recent years; there also seems to be a growing issue in the academic literature regarding the way it is handled as a valid form of technological addiction akin to video gaming addiction or internet addiction (Yu & Sussman, 2020). Some recent studies that investigate the concept from a critical point of view, concluding that smartphone addiction as commonly discussed in the academic literature does not meet the requirements to actually be referred to as an addiction and instead should be considered only as problematic use (Lowe-Calverley & Pontes, 2020; Panova & Carbonell, 2018). Panova and Carbonell use a metaphor of addicts making use of needle injections in administering the harmful substance heroin into their bodies and illustrate that smartphone is merely a delivery agent not unlike a needle that may or may not contain harmful substances or may or may not be used abusively. Jeong, Suh and Gweon's study (2020) therefore tries to somehow differentiate the "needle" from the "substance" somehow, investigating the factors contributing to both smartphone and internet addictions and coming up with conclusions that may be interpreted as internet addiction being the more comprehensive framework among the two. Supporting this claim, Chou & Chou (2019) have investigated a sample of Taiwanese students and discovered that heavy engagement with social networks, online games or online shopping via smartphones is the actual underlying cause of problematic smartphone use; regardless of gender or household income levels. Nevertheless, the claim stands that most studies in the literature handling the issue of smartphone addiction have failed to investigate the etiological origins or causal pathways of smartphone addiction (Yu & Sussman, 2020). A recent study employing magnetic resonance imaging and handling the issue on a medical standpoint, however, has investigated brain volume and neurological activity of participants scoring high on self-reported smartphone addiction scales (while excluding those who have scored high also on gaming addiction scales); and provided evidence that aberrant neurological activity hinting at a valid case of addiction is present in these individuals (Horvath et al., 2020).

Despite being a disputed concept, an overall glance at studies conducted throughout the better half of the previous decade shows that smartphone addiction is an alarming concern that continues to grow worldwide (Olson et al., 2020). Numerous studies in the recent have therefore especially investigated the phenomenon within an audience of adolescents and university students. This could be due to generation-z being born into a world of information technology as digital natives and thus having a greater risk of smartphone addiction accompanying a greater rate of technology adoption than older generations. Buctot et al. (2020) investigate the effect of smartphone addiction upon health-related quality of life in adolescents, which they break into the three categories of a) physical well-being, b) psychological well-being and c) school environment; and report that smartphone addiction negatively impacts all three elements of an adolescent's life. The underlying mechanics of smartphone addiction have been investigated and found to be associated with positive and negative reinforcement aspects of the reinforcement reward (such as dopamine release) concept; as well as habitual behavior (Chen et al., 2019). This is to say, smartphone users begin their problematic use patterns due to both feeling of enjoyment during time they spend using their devices and feeling of relief from negative emotions. In time, these reinforced use patterns develop into habits and become even more permanent. Moreover, it was also established by the study that people that find their smartphones as a resort for escaping negative feelings of daily life are more prone to develop an addiction than those who simply enjoy using their phone too much. Jeong et al. (2020) studied contributing factors to smartphone addiction in adolescents extensively, coming up with a list 12 factors that increase the risk in adolescents: a) Depression, b) Anxiety, c) Self-control, d) Life satisfaction, e) Aggression, f) Parent-Child communication time, g) Parent-Child Attachment, h) Parent-Child Relationship, i) Domestic Violence, j) Teacher Support, k) Teacher-Child Relationship and l) Learning Motivation. In another study, which investigated the contributing factor of parental neglect in adolescent smartphone addiction levels (Kwak et al., 2018), it was discovered that in addition to improving family relationships; expanding leisure activity grounds for adolescents and helping them develop healthier relationships with friends in the offline world would help decrease their smartphone addiction levels. Many studies take into account the factor of gender while investigating contributing factors to smartphone addiction; albeit coming up with inconsistent results. A recent study conducted among adolescents in Japan and Thailand has shown that in both countries, smartphone addiction was more prevalent in females than males (Tangmunkongvorakul et al., 2020). There exist however, other studies conducted within the same year that indicate opposite results (Buctot et al., 2020). A conclusive remark has been made by Olson and colleagues (2020), however, by carrying out a meta-analysis covering 82 studies conducted between 2014 and 2020 within 24 countries and discovering that smartphone addiction risk seems higher in younger and female populations.

Also working with adolescents, Chou & Chou (2019) have reported that parent-mediated control strategies are not effective in helping their children overcome problematic smartphone use. Defining self-regulation as 'self-generated thoughts, feelings and actions that are planned and cyclically adapted to the attainment of personal goals', Mahapatra (2019) investigated smartphone use in 330 adolescents and concluded that lack of self-regulation, alongside loneliness, signficantly predicts smartphone addiction likelihood. Kim et al. (2018) also dealt with the idea and discovered similar results by working with a group of 3380 Korean adolescents, reporting that friendship quality alongside self-control (which has been defined as 'an individual's ability to control his/her emotions, thoughts, and behaviors against impulses and temptations') skills help reduce smartphone addiction risk.

Researchers in Romania have conducted a comprehensive study to compare adolescents and university students in terms of smartphone use patterns within the scope of smartphone addiction (Cocoradă et al., 2018). They have concluded that high school students are more prone to confessing an addiction to their smartphones and that at this age group, smartphone addiction is more related to entertainment or communication related tasks such as heavy social-network-related use, gaming-related use, as well as video streaming and phone calling. University students, on the other hand, have reported using their smartphones for a greater variety of purposes and showed greater likelihood to experience a fear of missing out on technology use. In another study, Meena and colleagues report that in undergraduate students; smartphone addiction is associated with factors such as loneliness, shyness, social anxiety and external locus of control (Meena et al., 2021). Nevertheless, university students have been reported to suffer from problems like academic failure (Hawi & Samaha, 2016; Huang & Leung, 2009; Kibona & Mgaya, 2015), reduced physical and social activity level (Lepp et al., 2013; Kim et al., 2015; Samaha & Hawi, 2016), sleep problems (Sahin et al., 2013; Thomée et al., 2011) due to smartphone addiction. Like all other addictions, smartphone addiction also progresses gradually (Dinç, 2015) and it can be claimed that the rate of this progress is higher during free time, in which young people engage with their smartphones as a leisure activity. As discussed before, parental supervision is an important factor in preventing smartphone addiction in the young generation and yet, it should also be considered that university students are mostly individuals who have just left the boundaries of close parental supervision. Research in similar vein have displayed how university students mostly prefer spending time on the Internet during their leisure (Minaz & Bozkurt, 2017) and as reliance on information technology products such as social media and digital games as free time activities increases, so will the risk of addiction to these.

Free time may be defined as time during which an individual is capable of performing tasks and activities that a) lie outside of the boundaries of the individual's responsibilities and b) provide mental or physical fulfillment alongside a sense of enjoyment (İskender, 2019). For this reason, free time that is typically outside work hours is highly important for all people (Kuş-Şahin et al., 2009). Inclusion of enjoyable activities in their daily lives helps people feel vigorous and content. Proper use of free time also helps people alleviate boredom resulting from tedious daily routines and even helps increase work success (Yeniçeri et al., 2002). Although free time is highly influential on the welfare of both the individual and the society, many people fail to properly manage their free time. Whereas the success in free time management leads to individual and social progress; lack of success leads to individual and social problems (Yaşartürk et al., 2018). Kır (2007) has studied university students and similarly emphasizes the importance of availability of free time in character development and societal progress. The case of high school students is not entirely different, as displayed in Eranıl and Özcan's (2018) work, which reports that they are not very successful in managing their free time either and that as free time management skills get better in high school students, so do academic performance and relationship with parents. Free time management is closely tied with the scheduling skills and it has also been shown that better scheduling skill in university students is related to higher academic scores (Tektaş & Tektaş, 2010). As it is evident in the literature, free time is an important aspect of human life.

In order to manage free time well and prevent spending too much time on superfluous activities, individuals need to know their responsibilities and arrange their priorities accordingly (Aydoğan & Gündoğdu, 2006). Free time management requires the assessment of an individual's existing needs and demands, the setting of goals in order to meet these and the scheduling of these into a task sequence based on priority. Task-planning, scheduling and to-do lists are therefore important in arranging one's free time (Wang et al., 2012). However, it has been recently observed that the young generation is unable to manage their free time well and this results in them spending free time mostly by engaging with electronic products such as smartphones, computers and the Internet. (Tektaş & Tektaş, 2010; Minaz & Bozkurt, 2017). A study, which associates this phenomenon with personality traits and other circumstances has shown that young people who suffer from lack of a) choices for spending their free time, b) an active social circle, c) motivation to engage with any activity or interact with other people due to any number of reasons resort to technological devices, which are usually cheaper and more easily accessible than most other options, for avoiding boredom (Dinç, 2015). In today's world, the default choice of entertaining technological device is the smartphone and the diverse range of mobile applications that it offers. Being attached to the smartphone as the sole source of entertainment and relaxation is certain to invite the risk of smartphone addiction. A study by Wang (2019) covers internet addiction, which is another form of technological addiction, and reports that higher sense of boredom during one's free time is associated with greater risk of internet addiction and that free time management skills significantly help alleviate the feeling of boredom during free time. Under the light of such information, it may be extrapolated that skill in free time management may also help reduce the risk of smartphone addiction.

Hippocrates of Classical Greece, who is commonly considered the Father of Modern Medicine is quoted saying "The best way to cure a disease is to teach folks how not to fall victim to it in the first place". It is therefore important to investigate by academic research not only the effects of smartphone addiction but also its causes and preventive measures. A current glance at the literature shows lack of research investigating the relationship between smartphone addiction and free time management skills. The purpose of this research is to therefore investigate the relationship between smartphone addiction levels and free time management skills in university students. In this context, the following research questions have been formulated:

1. How prevalent is smartphone addiction in Turkish university students?

2. Is there a relationship between free time management skills and smartphone addiction in university students?
3. As far as university students are concerned, do better skills in managing one's free time help against smartphone addiction risk?

Method

Research Model

Similar to many studies in the literature investigating the relationships between smartphone addiction and certain factors, this quantitative, cross-sectional follows descriptive and correlational models. A descriptive model of research is where a population with numerous members is screened for entirely or partially through the use of a representative group or sample, in order to reach certain conclusions about the said population (Karasar, 1995). The correlational pattern seeks to establish the presence of a meaningful relationship between two or more variables via statistical tests of correlation (Creswell, 2012). The choice of correlational model is primarily due to the need to investigate whether the change in levels of smartphone addiction and free time management skills in university students generate a meaningful pattern.

Study Group

The population for this study has been designated as students enrolled at state universities in Turkey during the 2019-2020 academic year. Convenience sampling method has been employed to create a study group of 591 students studying in 45 different associate degree (2-year) or bachelor's degree (4-year) programs found in 4 Turkish universities. The study group is comprised of 164 (27,7%) males and 427 (72,3%) females. As for study years, 319 of the study group participants (54,0%) consists of freshman (1^{st} grade) students; whereas 101 participants were 2^{nd} year (17,1%), 42 were 3^{rd} year (7,1%) and 129 were 4^{th} year (21,8%) students. Average age of participants were found to be $\bar{X}$ =20,67. Demographic information of study group participants has been shown in Table 1.

Data Collection Instruments

A survey form prepared by the authors, which consists of four sections, has been used for the collection of data.

Section 1 – Personal Information

This section has been prepared to collect demographic data of participants; including gender, age, department of study and years studied in the said department.

Section 2 – The Smartphone Addiction Scale (SA-S)

The original version of the scale has been developed by Known et al. (2013) based on items prepared by Young (1998) pertaining to Internet addiction and the future of smartphones. The scale has been adapted to Turkish language by Demirci, Orhan, Demirdaş, Akpınar and Sert (2014). The Turkish Version of the Smartphone Addiction Scale is a reliable and valid instrument for assessing smartphone addiction risk. The factor analysis of this Turkish version showcases 7 factors in total and factor loads of items range between 0,349 to 0,824, with an overall score of 0,947 for the scale.

Sub-dimensions consist of "Daily-Life Disturbance" (5 items), "Positive anticipation" (8 items), "Withdrawal" (6 items), "Cyberspace-oriented Relationship" (7 items), "Overuse" (4 items) and "Tolerance" (3 items). The Smartphone Addiction Scale consists of 33 6-point Likert scale items with a score of 1 denoting "Certainly Disagree" and a score of 6 denoting "Certainly Agree". Total attainable scores range between 33 and 198 with higher scores attained on the scale being interpreted as greater risk of smartphone addiction. The study reports a Cronbach's Alpha reliability score of 0,92 for the scale.

Table 1. Demographic information on study group participants

Category	Frequency	Percentage
Gender		
Male	164	27,7
Female	427	72,3
Study Year		
1st Year	319	54,0
2nd Year	101	17,1
3rd Year	42	7,1
4rd Year	129	21,8
Program		
Elementary Education	59	10,0
English Language Education	54	9,1
Labor Economics and Industry Relations	32	5,4
Preschool Education	29	4,9
Culinary Arts	28	4,7
Psychological Guidance and Counseling	27	4,6
Child Development	25	4,2
Public Administration	25	4,2
Mathematics Education	23	3,9
Physical Education	20	3,4
Sports Administration	20	3,4
Business Administration	18	3,0
Medical Administration	17	3,0
Instructional Technology	15	2,9
Music Teaching	15	2,5
Economics	14	2,5
Turkish Language Education	14	2,4
Nutrition and Dietetics	12	2,4
International Relations	11	2,0
Management Information Systems	11	1,9
Nursing	10	1,9
Fine Arts Teaching	9	1,7
History	9	1,5
Sports Coaching	8	1,4
Finance	8	1,4
Tourism Administration	8	1,4
Turkish Literature	7	1,2
Veterinary Science	7	1,2
Computer Programming	5	0,8
Econometrics	5	0,8
Graphical Design	5	0,8
Albanian Language and Literature	4	0,7
Midwifery	4	0,7
Food Engineering	4	0,7
Social Sciences Education	4	0,7
German Language Education	3	0,5
Biology	3	0,5
Foreign Trade	3	0,5
Public Relations	3	0,5
Emergency Medical Care	3	0,5
Science Education	2	0,3
Physiotherapy	2	0,3
Mathematics	2	0,3
Special Needs Education	2	0,3
Sociology	2	0,3
Total	591	100,0

Free Time Management Scale (FTM-S)

The original version of the scale has been developed by Wang, Kao, Huan and Wu (2011), the form has been adapted to Turkish language by Akgül and Karaküçük (2015). The Free Time Management Scale (FTM-S), consists of 15 5-point Likert type items (1= Strongly Disagree, 5= Strongly Agree) and is divided into four sub-dimensions, namely "scheduling", "leisure attitude", "evaluation" and "goal setting". Cronbach's Alpha Reliability coefficient for the scale has been found to be 0.83 and test-retest reliability has been established as 0.86. Internal consistency coefficients for the sub dimensions range between .71 and .81. The reliability and validity studies also show that while the scale itself consists of four factors, it may also be used with a single factor (Akgül ve Karaküçük, 2015). In the study, the Cronbach Alpha value of the whole scale was determined as 0.84. The Cronbach alpha values of the sub-dimensions of the scale were determined as 0.89 for scheduling, 0.78 for evaluation, 0.77 for leisure attitude and 0.75 for goal setting, respectively.

Data Collection and Analysis

Data has been collected from university students via electronic forms prepared in Google forms, due to the fact that all universities in Turkey have switched to online education for the duration of the 2019-2020 global pandemic. Links of the electronic form have been shared with instructors in four Turkish universities and their help was asked in administering the form to their students at the end of their online classes. Data was collected from voluntary participants during a two-month period in October and November. Data collection procedure lasted approximately 10 to 15 minutes for each participant.

Several considerations have been made for the purpose of evaluating whether certain assumptions of various statistical tests have been met. First of all, normal distribution of data has been investigated in score sets of both SA-S and FTM-S. Skewness and kurtosis values for score set have been observed to range between -1,96 and +1,96, hence the assumption of normal distribution for each data set has been considered to be met (Tabachnick ve Fidell,2007). Therefore, the parametric statistical test of Pearson's correlation has been chosen to investigate the relationship between SA-S and FTM-S scores. Descriptive statistics for score sets from SA-S and FTM-S have been shown in Table 2.

Table 2. Kurtosis - Skewness values of the scales

Scales	N	Mean	Std. Error	Skewness	Kurtosis
SA-S	591	2,42	,775	,412	-,457
FTM-S	591	3,38	,757	-,039	-,560

In order to understand whether smartphone addiction risk is explained by score attained in the free time management scale or its sub-dimensions, a stepwise regression statistical test has been considered. An evaluation of test assumptions has revealed tolerance values greater than 0,10 (Tolerance=1,00; 0,997; 0,997) and VIF values smaller than 10, indicating there was no multicollinearity (Pallant, 2015). Durbin-Watson value of 1,760 has also shown that auto-correlation was not present, fulfilling assumptions for the stepwise regression test.

Results

Overall Levels of Smartphone Addiction and Free Time Management Skills in University Students

Descriptive statistics reveal that overall smartphone addiction risk levels in the study group is $\bar{X}$=2,43, whereas free time management scale average score is $\bar{X}$ =3,38. Further information regarding scores attained in scales and their respective sub-dimensions has been shown in Table 3.

The Relationship Between Free Time Management Skills and Smartphone Addiction in University Students

Correlation tests between scores from FTM-S and SA-S, reveals a weak-level statistically significant negative correlation (r=-,176, p<,01) between smartphone addiction risk and free-time management skills. Further analyses investigating correlation between scores in the sub dimensions (Scheduling, Leisure Attitude, Evaluation and Goal Setting) of the FTM-S and SA-S show a moderate-level statistically significant negative correlation between scheduling and smartphone addiction risk (r=-,390, p<,01). Other statistically significant correlations albeit at weak-levels have been shown to exist between smartphone addiction risk and the free time management sub dimensions of Evaluation (r=-.091, p<,05) and Goal Setting (r=-,148, p<,01). Lastly, a weak-level statistically significant positive correlation has been found between Leisure Attitude and smartphone addiction risk (r=,112, p<,01). Table 4 displays all results of the correlation tests in the matrix form.

Table 3. Descriptive statistics on scores attained in SA-S and FTM-S scales and their respective sub-dimensions

		Min.	Max	Avg.	SD
SA-S		1,03	4,58	2,43	,775
	Daily-Life Disturbance	1	6	2,85	1,117
	Positive Anticipation	1	6	2,66	1,050
	Withdrawal	1	5,71	1,97	,963
	Cyberspace-oriented Relationship	1	5,75	1,58	,893
	Overuse	1	5,50	2,64	1,098
	Social Media Addiction	1	6	2,51	1,359
	Physical Symptoms	1	6	2,78	1,011
FTM-S		1,27	5,00	3,38	,757
	Scheduling	1,00	5,00	3,57	,953
	Leisure Attitude	1,00	5,00	3,94	,974
	Evaluation	1,00	5,00	3,18	1,037
	Goal Setting	1,00	5,00	3,10	1,048

Table 4. Correlation matrix showing relationships between SA-S and FTM-S (and its sub dimensions)

	SA-S	FTM-S	Scheduling	Leisure Attitude	Evaluation	Goal Setting
SA-S	1	-,176**	-,390**	,112**	-,091*	-,148**
FTM-S		1	,601**	,446**	,733**	,715**
Scheduling			1	,053	,323**	,447**
Leisure Attitude				1	,272**	,183**
Evaluation					1	,738**
Goal Setting						1

*p<0,05

Predicting Smartphone Addiction Risk with Free Time Management Skills

Stepwise regression tests have been carried out in order to understand whether FTM-S overall or sub dimension scores may help predict SA-S scores. Results have shown that Scheduling and Leisure Attitude sub dimensions of Free Time Management are statistically significant predictors of Smartphone Addiction Risk, whereas Evaluation and Goal Setting sub dimensions have been found to be insignificant and thus removed from the regression model. According to the model, Scheduling and Leisure Attitude sub dimension scores in FTM-S account for 16.9% of the variance in SA-S scores; with Scheduling being a negative and Leisure Attitude being a positive predictor. Table 5 shows results of the stepwise regression test.

Table 5. Stepwise regression test for predicting smartphone addiction by free time management

		B	Std.Error	Beta	t	Tolerance	VIF
Model 1	(Constant)	3,560	,114		31,215**		
	Scheduling	-,317	,031	-,390	-10,269**	1,000	1,000
Model 2	(Constant)	3,163	,159		19,856**		
	Scheduling	-,323	,031	-,397	-10,541**	,997	1,003
	Leisure Attitude	,106	,030	,133	3,535**	,997	1,003

Model 1 = r: 390, R^2: ,152, F(2,588): 105,443, p < .01.
Model 2 = r: 412, R^2: ,169, F(2,588): 12,499, p < .01
*p<0,05 ; **p<0,01. Durbin-Watson=1,760.

Discussion and Conclusion

This study investigates the relationship between free time management skills and smartphone addiction risk in university students. A glance at the literature shows that the notion of free-time and personal traits associated with it, such as free-time satisfaction or management have not been evaluated within the context of technological addictions. In one study however, Yaman (2020) investigates addiction to the social networking service of Facebook and free-time satisfaction in university students; and reports no relationship between Facebook addiction risk and one's satisfaction with how one spends free time. This finding needs to be interpreted however, under the light of the fact that the Facebook social network is not as popular as it used to be among the younger generation (Hong & Oh, 2020).

In this study, findings of overall smartphone addiction risk in the study group have shown that smartphone addiction risk in university students may be considered low. Similar results have been achieved by Sağıroğlu and Akkanat (2019), who have studied 200 high school students and found similarly low scores in terms of smartphone addiction risk. Aktan (2018) reports another similar finding, indicating that overall social media addiction condition of university students may be explained as a "low level of addiction". However, contradictory results also exist in the literature reporting moderate (Haug et al., 2015; Çalışkan et al., 2017; Fazla et al., 2019; Akyürek, 2020) and high (Bianchi & Phillips, 2005; Minaz & Bozkurt, 2017; Kwon et al., 2013) overall levels of smartphone addiction risk in university students. Collectively, these contradicting findings may perhaps indicate that smartphone addiction levels vary as influenced by different factors such as socio-economic structure, culture, age group at regional and international levels.

The study also reflects a negative relationship between smartphone addiction risk and free time management skills in university students. In other words, as far as university students are concerned, as failure to manage one's free time increases, so does one's risk of developing an addiction to smartphone use. Yeşildal and Üstünbaş (2019) have reported similar results in a study they have conducted with 298 university students in another type of addiction; showcasing weak yet statistically significant negative correlation between free time management and risk of addiction to social media. Another study conducted with 165 university students in a school of nursing, which investigated the relationship between free time management and internet addiction, has also shown a moderate-level statistically significant negative correlation between the variables (Eroğlu & Kutlu, 2020). In Fazla et al.'s (2019) study, the choice of reading as a leisure activity has been shown to be associated with a decreased level of smartphone addiction risk in university students. Lastly, Wang (2019) reports that better skill in managing one's free time helps reduce boredom in university students and that boredom, in turn, translates into higher risk of internet addiction. It can be claimed that better skill in free time management, which may be interpreted in individual's active or passive participation in relaxing and/or productive activities that help maintain progressive development and inner peace, is one of the important elements in the struggle against addiction to information technology products.

Free-time management skill may be broken down into its sub-skills. The investigation of the relationship of these sub-skills with smartphone addiction in this study has also produced meaningful results. The “Scheduling” sub-skill of free-time management has been shown to be negatively correlated at a moderate-level with smartphone addiction risk; whereas "Evaluation" and "Goal Setting" also seem to have weak-level negative correlations with the latter. These findings may indicate that those university students who are unable to set well-defined goals for themselves, arrange their free time into an organized schedule or successfully evaluate the notion of free time may carry higher risk of smartphone addiction. On the other hand, as far as leisure attitude scores are concerned, the correlation with smartphone addiction risk seems to be positive.

University students may be considered as a group of individuals that have the freedom to decide and plan out when their free time begins and how to use that free time (Wang et al., 2012). That said, many undergraduate students have been reported to mismanage their free time and encounter feelings of boredom, which lead to behavioral problems like internet addiction (Wang, 2019). In Selçuk's (2019) study, it has been demonstrated that difficult in managing one's free time is associated with poor skills in self-regulation and that feelings of boredom coinciding with one's leisure time bolsters social media addiction risk. Sun and Kawthur (2013) indicate that university students commonly report "lack of time", "having to study all the time" and "lack of motivation" as reasons for being unable to manage their free time well. Lastly, it has also been reported in a study, which emphasizes not only the preventive but also the remedial aspect of free time management, that successful management of one's free time is an important element in overcoming internet addiction and that constructive use of free time helps reduce time spent using the internet by increasing face to face social contact (Van Rooij et al., 2012).

In the last part of the study, the predictive quality of free-time management skill and its sub-skills in determining smartphone addiction risk have been evaluated. Regression tests have shown that a model consisting of Scheduling and Leisure Attitude sub-skills predicted 16,9% of variance in smartphone addiction risk. In addition, the strongest predictor of smartphone addiction risk seems to be the scheduling sub-skill with 15,2% of variance explained. These findings may be interpreted as poor scheduling of one's free time in university students leading to smartphone addiction risk. That said, leisure attitude also predicts smartphone addiction risk, albeit minimally and in the opposite direction. A study by Kaya (2015) reveals that individuals engaging in physical activities during their leisure time display significantly more positive leisure attitude than those who don't. Interestingly enough, Kaya's paper also reports that positive leisure attitude is also associated with higher smartphone addiction risk; confirming the positive prediction of smartphone addiction risk by leisure attitude discovered in this study.

Recommendations

A meta-analysis that covers randomized control trials measuring the effectiveness of psychological interventions targeting adolescents for recovery from smartphone or internet addiction revealed that; educational programming or sandplay therapy are effective methods on reducing addiction severity (Malinauskas & Malinauskiene, 2019). Whereas, another meta-analysis research has shown that sports and physical exercise are effective methods in treating smartphone addiction, especially for those with a severe level of addiction (Liu et al., 2019). An interesting finding from research conducted in Malaysia however, indicates that as far as university students are concerned, maintaining an active physical life also helps reduce risk of smartphone addiction, only insofar as the addiction is caused by excessive mobile gaming related use (Abbasi et al., 2021). The same study reports that the same cannot be said for entertainment-related or social-network-related excessive use; i.e. no matter the level of physical activity in daily life, a person may still be smartphone addicted due to depending on the device for entertainment or social interaction.

In the end, it could be said that as far as university students are concerned, smart and purposeful scheduling of one's leisure time leads to reduced risk of smartphone addiction. And yet, it should be noted that free-time management is not synonymous with simply "staying away from the smartphone" through various lifestyle changes such as increasing the daily amount of physical activity. A study has showcased the inclusion of a course on free time management into the college curriculum has positively influenced students, enabling them to better organize their free time and turn boring situations into stimulating experiences (Caldwell et al., 2004). Tükel has also investigated the relationship between smartphone addiction and leisure satisfaction in 855 university students, showcasing that these variables are negatively correlated; also remarking that participation in athletic but also cultural or social activities was also positively associated with leisure satisfaction. However, it is known that today, university students mainly resort to electronic devices and most especially Internet use for spending their free time (Minaz & Bozkurt, 2017). Failure to manage free time well by choosing and engaging in proper recreational activities may therefore end up with one's free time being spent entirely on smartphones, the Internet, social media or digital games with a risk of addiction. Such overuse or addiction may in turn, lead to time loss, disruptions in daily routine, mental stress or even deterioration of physical health (Yeşildal & Üstünbaş, 2019). In this sense, the findings of this here study may be beneficial to the academic literature, in that, importance of free time management skills in university students has once again been emphasized. Literature also suggests that starting from adolescence; parents and educational institutions need to support students in terms of free time management and participation in leisure activities (Aksoy, 2018; Bulduklu & Özer, 2016; Sun & Kawthur, 2013). Lastly, it should be considered that efficient and active use of free time translates not only into physical and mental health improvement for university students (Arı, 2017; Macan, 1990; Alay & Koçak, 2003) but also into social, cultural and career development potential.

The Relationship Between Free Time Management Skills and Smartphone Addiction in University Students

Correlation tests between scores from FTM-S and SA-S, reveals a weak-level statistically significant negative correlation ($r=-,176$, $p<,01$) between smartphone addiction risk and free-time management skills. Further analyses investigating correlation between scores in the sub dimensions (Scheduling, Leisure Attitude, Evaluation and Goal Setting) of the FTM-S and SA-S show a moderate-level statistically significant negative correlation between scheduling and smartphone addiction risk ($r=-,390$, $p<,01$). Other statistically significant correlations albeit at weak-levels have been shown to exist between smartphone addiction risk and the free time management sub dimensions of Evaluation ($r=-.091$, $p<,05$) and Goal Setting ($r=-,148$, $p<,01$). Lastly, a weak-level statistically significant positive correlation has been found between Leisure Attitude and smartphone addiction risk (r=,112, p<,01). Table 4 displays all results of the correlation tests in the matrix form.

Limitations

This study followed a convenience sampling method in the inclusion of participants from three Turkish state universities to represent an entire population of Turkish undergraduate university students. As such, disproportionate amount of members has been included in many demographic categories such as gender or study year. Advanced sampling methods, such as quota sampling, could have served to represent the population more accurately. Being an introductory study in investigating relationship between free-time management and smartphone addiction; it also employed rudimentary statistical methods for explaining the relationship between variables, partly due to violation of assumptions for more advanced techniques, such as structural equation modeling. Future studies may improve upon these findings by employing such tests for analysis. Moreover, qualitative research methods, which were omitted in this study, may also have been useful for maintaining a deeper investigation of how exactly those scoring higher in the free-time management scale spend their free-time as opposed to those who score lower.

Acknowledgement

This study was produced from the thesis titled "*Smartphone addiction in University students: A research on recreational activity participation behaviors and leisure management*" conducted at the Trakya University Institute of Social Sciences, Department of Recreation and has been financially aided by the Turkish Green Crescent Society Graduate Scholarship Program during the 2020/8 period.

Scientific Ethics Declaration

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

References

Abbasi, G. A., Jagaveeran, M., Goh, Y. N., & Tariq, B. (2021). The impact of type of content use on smartphone addiction and academic performance: Physical activity as moderator. *Technology in Society*, *64*, 101521.

Ada, S., & Tatlı, H. (2012). *An Investigation on factors affecting the use of smartphones*. K. Maraş Sütçü İmam University, Faculty of Administrative and Economic Sciences, Kahramanmaraş, Turkey.

Akgül, B. M., & Karaküçük, S. (2015). Free time management scale: Validity and reliability analysis. *Journal of Human Sciences*, *12*(2), 1867-1880.

Akın, A., Altundağ, Y., Turan, M. E., & Akın, Ü. (2014). The validity and reliability of the Turkish version of the smart phone addiction scale-short form for adolescent. *Procedia - Social and Behavioral Sciences, 152*, 74-77

Aktan, E. (2018). Assessment of social media addiction levels of university students by numerous variables. *Erciyes Journal of Communication*, *5*(4), 405-421.

Aksoy, Z. (2018). *Game addiction, life style behaviors and affecting factors in adolescents*. (Master's thesis, Marmara University, Istanbul, Turkey).

Akyürek, M. İ. (2020). Smart phone use and addiction of high school students. *Turkish Journal of Educational Studies*, *7*(2), 42-63.

Alay, S. & Koçak, S. (2002). Validity and reliability of time management questionnaire. *Hacettepe University Journal of Education*, *22*, 9–13.

Arı, Ç. (2017*). Study of the relationship between free time management and quality of life of candidates teachers registered in pedagogical formation* (Doctoral dissertation, Yıldırım Beyazıt University Institute of Health Sciences, Ankara, Turkey).

Bal. E., & Balcı, Ş. (2020). Smartphone addiction: A study on efficacy of personality traits and usage patterns. *Erciyes Journal of Communication*, *7*(1), 369-394.

Bianchi A, & Phillips J. (2005). Psychological predictors of problem mobile phone use. *CyberPsychology and Behavior*, *8*(1), 39-51.

Brooks, F. M., Chester, K. L., Smeeton, N. C., & Spencer, N. H. (2016). Video gaming in adolescence: factors associated with leisure time use. *Journal of Youth Studies*, *19*(1), 36-54.

Buctot, D. B., Kim, N., & Kim, J. J. (2020). Factors associated with smartphone addiction prevalence and its predictive capacity for health-related quality of life among Filipino adolescents. *Children and Youth Services Review, 110*, 104758.

Bulduklu, Y., & Özer, N. P. (2016). Young people's smart phone use motivations. *Journal of the Human & Social Science Researches*, *5*(8), 2963-2986.

Caldwell, L. L., Baldwin, C. K., Walls, T., & Smith, E. (2004) Preliminary effects of a leisure education program to promote healthy use of free time among middle school adolescents. *Journal of Leisure Research, 36*, 310–335.

Chen, C., Zhang, K. Z., Gong, X., & Lee, M. (2019). Dual mechanisms of reinforcement reward and habit in driving smartphone addiction. *Internet Research*, *29*(6), 1551-1570.

Chou, H. L., & Chou, C. (2019). A quantitative analysis of factors related to Taiwan teenagers' smartphone addiction tendency using a random sample of parent-child dyads. *Computers in Human Behavior, 99*, 335-344.

Cocoradă, E., Maican, C. I., Cazan, A. M., & Maican, M. A. (2018). Assessing the smartphone addiction risk and its associations with personality traits among adolescents. *Children and Youth Services Review, 93*, 345-354.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research (4th ed.).* Boston, MA: Pearson Education, Inc.

Demirci, K., Orhan, H., Demirdas, A., Akpinar, A., & Sert, H. (2014). Validity and reliability of the Turkish version of the smartphone addiction scale in a younger population. *Bulletin of Clinical Psychopharmacology*, *24*(3), 226-234.

Dinç, M. (2015). Youth and technological addiction. *Journal of Youth Studies*, *3*(3), 31-65.

Eroğlu, Ç., & Kutlu, A. (2020). Determination of the relationship between internet addiction and time management in nurses. *Celal Bayar University Journal of Health Sciences Institute*, *7*(2), 110-116.

Fazla, S., Akcan, M., Sümer, O. N., & Gezgin, D. M. (2019). Investigation of the relationship between high school students' reading habits and smartphone addiction levels. 7th *International Instructional Technology and Teacher Education Symposium*, Antalya, Turkey.

Griffiths, M. (2005). A 'components' model of addiction within a biopsychosocial framework. *Journal of Substance Use*, *10*(4), 191-197.

Hawi, N. S., & Samaha, M. (2016). To excel or not to excel: Strong evidence on the adverse effect of smartphone addiction on academic performance. *Computers & Education, 98*, 81-89.

Haug, S., P. Castro, R., Kwon, M., Filler, A., Kowatsch, T., & P. Schaub, M. (2015). Smartphone use and smartphone addiction among young people in Switzerland. *Journal of Behavioral Addictions, 4*(4), 299-307.

Hong, S., & Oh, S. K. (2020). Why people don't use facebook anymore? An investigation into the relationship between the big five personality traits and the motivation to leave facebook. *Frontiers in Psychology, 11*, 1497.

Horvath, J., Mundinger, C., Schmitgen, M. M., Wolf, N. D., Sambataro, F., Hirjak, D., ... & Wolf, R. C. (2020). Structural and functional correlates of smartphone addiction. *Addictive Behaviors*, *105*, 106334.

Jin Jeong, Y., Suh, B., & Gweon, G. (2020). Is smartphone addiction different from Internet addiction? comparison of addiction-risk factors among adolescents. *Behaviour & Information Technology, 39*(5), 578-593.

Karasar, N. (2005). *Scientific Research Methods.* Ankara: Nobel Publications.

Kaya, S. (2015). An examination of university students' attitudes towards leisure activities. *Pamukkale Journal of Sports Sciences*, *6*(3), 46-60.

Kır, İ., (2007). Leisure Activities Of Higher Education Youth: KSÜ Example. *Fırat University Journal of Social Sciences. 17*(2): 307-328

Kibona, L., & Mgaya, G. (2015). Smartphones' effects on academic performance of higher learning students. *Journal of Multidisciplinary Engineering Science and Technology*, 2(4), 777-784.

Kim, H. J., Min, J. Y., Min, K. B., Lee, T. J., & Yoo, S. (2018). Relationship among family environment, self-control, friendship quality, and adolescents' smartphone addiction in South Korea: Findings from nationwide data. *Plos one*, *13*(2), e0190896.

Kim, S. E., Kim, J. W., & Jee, Y. S. (2015). Relationship between smartphone addiction and physical activity in Chinese international students in Korea. *Journal of Behavioral Addictions*, *4*(3), 200-205.

Köse, D., Çınar, N. & Akduran, F. (2012). The relationship of personality traits and time management between internet addiction in students of a nursing school. *Sakarya University Journal of Science, 16*(3), 227-233.

Kuş Şahin, C , Akten, S., & Erol, U . (2011). A study to determine recreational participation tendency of the eğirdir vocational school students. *Artvin Çoruh University Journal of Forestry Faculty*, *10*(1), 62-71.

Kwak, J. Y., Kim, J. Y., & Yoon, Y. W. (2018). Effect of parental neglect on smartphone addiction in adolescents in South Korea. *Child Abuse & Neglect, 77*, 75-84.

Kwon, M., Lee, J. Y., Won, W. Y., Park, J. W., Min, J. A., Hahn, C., ... & Kim, D. J. (2013). Development and validation of a smartphone addiction scale (SAS). *PloS one*, *8*(2), e56936.

Lepp, A., Barkley, J. E., Sanders, G. J., Rebold, M., & Gates, P. (2013). The relationship between cell phone use, physical and sedentary activity, and cardiorespiratory fitness in a sample of US college students. *International Journal of Behavioral Nutrition and Physical Activity, 10*(1), 79.

Liu, S., Xiao, T., Yang, L., & Loprinzi, P. D. (2019). Exercise as an alternative approach for treating smartphone addiction: a systematic review and meta-analysis of random controlled trials. *International Journal of Environmental Research and Public Health, 16*(20), 3912.

Lowe-Calverley, E., & Pontes, H. M. (2020). Challenging the concept of smartphone addiction: An empirical pilot study of smartphone usage patterns and psychological well-being. *Cyberpsychology, Behavior, and Social Networking, 23*(8), 550-556.

Macan, T.H. (1990). College students' time management: correlations with academic performance and stress. *Journal of Educational Psychology, 82*(4), 760-768.

Mahapatra, S. (2019). Smartphone addiction and associated consequences: Role of loneliness and self-regulation. *Behaviour & Information Technology, 38*(8), 833-844.

Malinauskas, R., & Malinauskiene, V. (2019). A meta-analysis of psychological interventions for Internet/smartphone addiction among adolescents. *Journal of Behavioral Addictions, 8*(4), 613-624.

Meena, M. E., Kang, S., Nguchu, B. A., Milly, N., Makwetta, J. J., & Fomude, A. H. (2021). Empirical Analysis of Factors Contributing to Smartphone Addiction. *Open Journal of Business and Management, 9*(01), 213.

Minaz, A., & Bozkurt, Ö. Ç. (2017). Investigation Of University Students Smartphone Addiction Levels And Usage Purposes In Terms Of Different Variables. *Mehmet Akif Ersoy University Journal of the Social Sciences Institute*, *9*(21), 268-286.

Olson, J. A., Sandra, D., Colucci, É. S., Al Bikaii, A., Nahas, J., Chmoulevitch, D., ... & Veissière, S. P. (2020). Smartphone addiction is increasing across the world: A meta-analysis of 24 countries. *PsyArXiv.*

Panova, T., & Carbonell, X. (2018). Is smartphone addiction really an addiction?. *Journal of Behavioral Addictions*, *7*(2), 252-259.

Park, N., & Lee, H. (2011). Social implications of smartphone use: Korean college students' smartphone use and psychological well-being. *Cyberpsychology, 15,* (9), 491–497.

Sahin, S., Ozdemir, K., Unsal, A., & Temiz, N. (2013). Evaluation of mobile phone addiction level and sleep quality in university students. *Pakistan Journal of Medical Sciences, 29*(4), 913.

Sağıroğlu, K. E., & Akkanat, Ç. (2019). Investigating smart phone addiction of high school students. *Online Journal of Technology Addiction and Cyberbullying*, *6*(2), 1-16.

Samaha, M., & Hawi, N. S. (2016). Relationships among smartphone addiction, stress, academic performance, and satisfaction with life. *Computers in Human Behavior, 57*, 321-325.

Selçuk, O. C. (2019*). Risk factors for internet addiction: insufficient self-regulation and leisure boredom.* (Master's thesis, Adnan Menderes University, Aydın).

Sun, M. C., & Kawthur, B. A. (2013). Leisure-time physical activity among university students in Mauritius. *American Journal of Health Research*, *1*(1), 1-8.

Tangmunkongvorakul, A., Musumari, P. M., Tsubohara, Y., Ayood, P., Srithanaviboonchai, K., Techasrivichien, T., ... & Kihara, M. (2020). Factors associated with smartphone addiction: A comparative study between Japanese and Thai high school students. *Plos one*, *15*(9), e0238459.

Tektaş, M., & Tektaş, N. (2010). The relationship between vocational school student's academic success and time management. *The Journal of Selcuk University Social Sciences Institute*, *23*, 221-229.

Thomée, S., Härenstam, A., & Hagberg, M. (2011). Mobile phone use and stress, sleep disturbances, and symptoms of depression among young adults-a prospective cohort study. *BMC public health*, *11*(1), 66.

Tükel, Y. (2020). Investigation of the relationship between smartphone addiction and leisure satisfaction of university students. *International Journal of Technology in Education and Science, 4*(3), 218-226.

Van Rooij, A., Zinn, M., Schoenmakers, T., Mheen, D. (2012) Treating internet addiction with cognitive-behavioral therapy: A thematic analysis of the experiences of therapists. *International Journal of Mental Health & Addiction*, *10*(1), 69–82.

Wang, W. C. (2019). Exploring the relationship among free-time management, leisure boredom, and internet addiction in undergraduates in Taiwan. *Psychological reports, 122*(5), 1651-1665.

Wang, W. C., Wu, C. Y., Wu, C. C., & Huan, T. C. (2012). Exploring the relationships between free-time management and boredom in leisure. *Psychological Reports*, *110*(2), 416-426.

Yaman, M. S. (2020). Investigation of the relationship between facebook addiction and the level of free time satisfaction of the recreation department students. *Turkish Online Journal of Educational Technology*, *19*(3), 51-59.

Yaşartürk, F., Akyüz, H., & Karataş, İ. (2018). The investigation of the relationship between recreation department students' organizational factors affecting their academic achievement and leisure management. *Journal of Sport Sciences Researches*, *3*(2), 233-243.

Yeniçeri, M., Coşkun, B., & Özkan, H. (2002). A research on the free-time management tendencies of public servants in the province of Mugla. *Muğla Sıtkı Koçman University Journal of Social Sciences and Humanities Research*, *7*.

Yeşildal, M., & Üstünbaş, B. N. (2019). An ineffective leisure management result: social media addiction. *4th International Health Sciences and Management Conference*, Istanbul Turkey.

Young KS (1998). Internet addiction: The emergence of a new clinical disorder. *CyberPsychology Behaviours*, *1*, 237-44.

Yu, S., & Sussman, S. (2020). Does smartphone addiction fall on a continuum of addictive behaviors?. *International Journal of Environmental Research and Public Health*, *17*(2), 422.

Yusufoğlu, Ö. Ş. (2017). Smart phones as leisure activities and their impact on social life: A research on students of the university. *Journal of the Human & Social Science Researches*, *6*(5), 2414-2434.

Author(s) Information

Deniz Mertkan Gezgin
Trakya University Faculty of Education
Edirne, Turkey
Contact e-mail: *mertkan@trakya.edu.tr*
ORCID iD: 0000-0003-4688-043X

Can Mıhcı
Trakya University Faculty of Education
Edirne, Turkey
ORCID iD: 0000-0001-9393-4619

Sinem Gedik
Trakya University
Edirne, Turkey
ORCID iD: 0000-0002-1898-3629