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Balıkesir University Çağış Campus 10145 Balıkesir
Tel: +90 (266) 612 14 00-08
Fax: +90 (266) 612 14 17
e-mail: efmed@balikesir.edu.tr
https://dergipark.org.tr/en/pub/balikesirnef

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Electronic Journal of Science and Mathematics Education

JUNE 2024 VOLUME 18 ISSUE 1

CONTENTS

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EDITOR'S NOTE

Dear Readers,

After an intensive working process, as the editorial board of Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, we are very pleased to publish the 1st issue of the 18th volume of our journal with our authors and referees. In this issue, there are 8 research articles on different topics. We hope that these articles will be read with interest make valuable contributions to the field and shed light on further research. We would like to thank our editorial team for their efforts in the publication of this issue, our referees who contribute to the quality of our journal with their meticulous article evaluations, and our authors who contribute to our journal with their qualified and original articles. We thank you for all the support you have given to our journal so far and will give in the future. We wish you enjoyable reading.

Editor

Dr. Mustafa ÇORAMIK

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Research Article

The Effect of STEM Education Practices on the Awareness towards STEM Education and Opinions of Preservice Science Teachers*

Hüsnüye DURMAZ[1], Hande ÇELİK KESER[2]

[1] Trakya University, Faculty of Education, Türkiye, husniyedurmaz@trakya.edu.tr, https://orcid.org/0000-0002-0553-3223
[2] Trakya University, Institute of Natural Sciences, Türkiye, handecelik91@gmail.com, https://orcid.org/0000-0003-3835-2821

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Abstract – This study aims to examine the effects of STEM education practices on preservice science teachers' (PSTs) awareness of STEM and STEM education and their views on the implementation process. The study was designed as a one-group pretest/posttest weak-experimental design including a case study. The participants were 30 PSTs enrolling in the Science Teaching Laboratory Applications I course in the 2018-2019 academic year and were determined by convenience sampling. In the study that lasted nine weeks, five STEM activities were practiced. STEM awareness open-ended questionnaire (STEM-A) was administered as pre and posttest, and the obtained data was evaluated with the thematic analysis. At the end of the instructional practices, semi-structured interviews were conducted with ten volunteer participants and the data were analyzed with the content analysis method. According to the findings, it can be stated that the participants' awareness developed positively and they grasped the importance of interdisciplinary relationship and integrated structure of the STEM approach.

Keywords: Preservice science teachers, STEM education, STEM awareness.

Corresponding author: Hüsnüye DURMAZ, husniyedurmaz@trakya.edu.tr

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* This study includes a part of the second author's Master's thesis titled "Effects of the STEM Education on Pre-service Science Teachers' Awareness on STEM Education, Scientific Creativity and Skills of Problem Solving" conducted under the supervision of the first author and was presented at the second International Necatibey Education and Social Sciences Research Congress (INESRC2023). In addition, the results obtained from the pilot study were presented in the 13th International Balkan Education and Science Congress (BES2018).

Introduction

In today's rapidly changing society, the quality of education plays a crucial role in enabling societies to adapt to social, economic, cultural, and technological advancements. One of the key factors that determine the quality of education is the proficiency of trained teachers, as well as the successful implementation of contemporary learning and teaching methodologies.

When the innovative educational approaches of countries around the world are examined within the framework of science education in recent years, *STEM education*, which is integrated with different understandings, methods, and techniques of **S**cience, **T**echnology, **E**ngineering, and **M**athematics disciplines and is based on an interdisciplinary learning approach, has attracted attention (Bybee, 2013). Although there are different definitions for STEM education in the literature (Dare et al., 2019; Moore et al., 2020), based on the common features in these definitions, we will define it as STEM education includes purposefully integration of various disciplines used to solve real-world problems integration (Breiner et al., 2012). Roehrig and colleagues (2021) propose seven main characteristics for an integrated STEM unit or curricula: Starting with a real-world problem; centering the engineering cycle; ensuring content integration for interdisciplinary; promoting context integration for interdisciplinary; STEM practices; 21st century skills; creating career awareness about STEM disciplines.

One of the fundamental approaches to keep abreast of developments in STEM education is to provide comprehensive training for teachers as competent STEM practitioners. To ensure that, preservice teachers (PTs) should be recognized as individuals who require education that incorporates interdisciplinary integration during their pre-service period, along with opportunities to design and implement teaching methodologies that include STEM integration (Harlen, 2015). Thus, PTs will be able to develop a comprehensive understanding of how to meaningfully and accurately integrate STEM disciplines into their future class practices (Bartels et al., 2019). If learners are not taught how to effectively integrate different disciplines, they may encounter challenges when exploring related topics and making connections between them (You, 2017). The implementation of STEM education depends largely on factors such as teachers' perceptions, attitudes, educational backgrounds, and competencies (Khuyen et al., 2020; Thibaut et al., 2018). PTs' understanding and experience of STEM education will influence their intentions to implement STEM in their schools. For these reasons, there is a need to investigate preservice science teachers' (PSTs') awareness of

STEM and STEM education and their views about STEM education. STEM awareness is increasing individuals' awareness levels in this field by focusing their interests and perceptions on STEM education (Buyruk & Korkmaz, 2016). When the related literature was examined, it was determined that participants' STEM awareness was generally measured with quantitative data collection tools (Buyruk & Korkmaz, 2016; Çevik, 2017; Faikhamta, 2020; Mai et al., 2023). On the other hand, Radloff and Guzey (2016) examined how PSTs conceptualized STEM education using a data collection tool with a total of 12 questions containing different question types, using a survey method without instructional intervention. Based on the data they obtained, Radloff and Guzey suggested that there was a great diversity in PTs' concepts of STEM education. In addition, Radloff and Guzey (2017) applied a video-based instructional intervention (observing, analyzing, and reflecting on integrated STEM teaching approaches) for a period of time through semi-structured pre- and post-interviews. Aydın-Günbatar et al. (2021) examined the changes in PSTs' concepts of STEM education using the mental model protocol before and after the instructional intervention focused on the engineering-design process. In both studies (Aydın-Günbatar et al., 2021; Radloff & Guzey, 2017), the researchers stated that STEM training was effective in PSTs' conceptualization of the integrated STEM approach. We conducted an instructional intervention and preferred to use a qualitative measurement tool to understand the awareness of future teachers more clearly about STEM or STEM education so that they can become qualified STEM education practitioners. The open-ended data collection tool developed by Tezsezen (2017) to examine the STEM awareness of PSTs differs from the qualitative data collection tools used in aforementioned studies because it also includes the "experience component" dimension regarding STEM awareness. Although developing an understanding of the nature of STEM requires more than the sum of the nature of science, the nature of technology, the nature of engineering, and the nature of mathematics, teachers should have a basic understanding and knowledge of all four STEM disciplines and how to make meaningful explicit connections among these disciplines. They also need to gain experience in creating learning environments that will present this knowledge and connections to their students (Akerson et al., 2018). For this reason, this qualitative case study was preferred to provide PSTs with the opportunity to experience STEM practices and to obtain richer data to reveal how they conceptualize STEM. Moreover, taking into account STEM literacy (Zollman, 2012), which requires the use of scientific concepts, processes and understandings from different disciplines in encountered situations, we aimed to illuminate whether PSTs noticed the relationships between STEM disciplines in two examples presented from daily life. Drawing from Tezsezen's study (2017), our examination of the “knowledge component” of STEM awareness involved analyzing how PSTs describe each STEM discipline. Similarly, to explore the “experience component” of STEM awareness, we focused on how PSTs depict each STEM discipline within the context of everyday STEM-related topics.

STEM teacher training holds immense importance due to the limited or even nonexistent exposure to STEM education during teachers' pre-service training. Moreover, opportunities for professional development in integrated STEM education remain scarce for PSTs (Brown & Bogiages, 2019; Lo, 2021; Wang et al., 2020). Furthermore, PSTs who engage in STEM practices often experience feelings of anxiety, fear, and self-inadequacy regarding the execution of these practices (Eren & Dökme, 2022). For these reasons, to encourage PSTs to receive and apply preservice STEM education has vital importance. This study involved creating an instructional environment where PSTs could experience STEM education practices in both student and teacher roles. The objective of this study, which is part of a larger research investigating the effects of STEM education practice on the PSTs, is to investigate the impact of these practices on their awareness of STEM and STEM education, as well as their perspectives on the implementation process.

This research seeks to address the following questions:

1- Does STEM education have an effect on PSTs' awareness of STEM and STEM education?

2- What are the views of PSTs regarding STEM education?

Method

We designed the study based on the weak-experimental design with a One-Group Pretest-Posttest model (Creswell, 2014) by including a case study. Case study, widely used in qualitative research, is preferred to examine one or more cases (situation, event, individual, group, etc.) in depth within their own conditions (Yıldırım & Şimşek, 2021). Moreover, as mentioned above, we preferred this qualitative case study to obtain richer data to reveal how they conceptualize the concept of STEM and all four disciplines separately, and whether the PSTs can recognize the relationships/connections among STEM disciplines in the daily life examples. Qualitative data were gathered through open-ended questions placed in both questionnaire and interview form.

Participants

This study consists of 30 third-grade PSTs studying in the science teaching program of the faculty of education of a state university in a provincial center located in the north-west of Türkiye in the 2018-2019 academic year. We determined the participants based on convenience sampling method and a voluntary basis to speed up the research and avoid problems in contact, although its reliability and generalizability are lower than other sampling methods (Yıldırım & Şimşek, 2021). The researchers explained the purpose and content of the research to the PSTs enrolled in the Science Teaching Laboratory Applications I course, and 30 PSTs stated that they would participate in the study voluntarily. Participants consisted of 24 female and six male science PSTs with an average age of 20-21. According to the science teaching undergraduate program used in the 2018-2019 academic year when the study was conducted, the participants generally completed physics, chemistry, biology, and mathematics courses and have not yet enrolled in the science teaching methods course (Council of Higher Education, 2018). 40% of the participants stated that they had never heard of the concept of STEM before.

Data Collection Tools

STEM-Awareness open-ended questionnaire (STEM-A)

This questionnaire, developed by Tezsezen (2017), consists of two parts including open-ended questions, and was used as a pre and posttest. The first part contains two questions. Participants were asked to define STEM disciplines in the first question and STEM education in the second question. In the second part, there are reading texts on two situations (*Microbiological corrosion* and *Radioactive verbs*) selected from daily life topics. To reveal whether or not they realize the relationship between STEM disciplines, participants were asked to explain which STEM disciplines are included in these reading texts. The STEM-A was administered as pre and posttest.

Semi-structured interview form

There are four questions in the form. Expert opinions were obtained from two science educators for the content validity of the prepared interview questions. To reveal participants' awareness of the applicability of STEM practicing, interviews were held with ten volunteer PSTs at the end of the instructional intervention. Interview questions are listed below:

1- In which subjects do you think you can include STEM practices within the scope of science courses in your professional life?
2- What do you think you would need if you were to use these practices in your professional life?
3- In your opinion, what is the key to making STEM practices productive (or, what does the efficiency of a STEM practice depend on)?
4- How do you include other STEM disciplines other than science in your practices?

Instructional Implementation Process

The second researcher carried out the practices in the study under the supervision of the first researcher. First of all, a four-week pilot study was conducted on a voluntary basis with 27 third grade PSTs who enrolled in the Science Teaching Laboratory Applications II course in the spring semester of the 2017-2018 academic year. During this study, three activities (*Let's design a thermos, Let's design a wind turbine, and Let's produce bioplastic*) prepared based on the literature (BAUSTEM, 2018; Çepni, 2018; Çorlu & Çallı, 2017; National Aeronautics and Space Administration [NASA], 2018a) were carried out. The data and findings obtained from the pilot study were used in the development of this study. Considering the difficulties encountered during the pilot study and the suggestions of the participants, we thought that it would be useful to prepare a worksheet that PSTs can use during STEM practices, and decided that the materials to be used in the new STEM practices to be designed would be mostly easily accessible and/or recyclable materials.

The study was conducted over a nine-week period with 30 third grade students enrolled in the Science Teaching Laboratory Applications I course in the 2018-2019 academic year. Practices were carried out in heterogeneous groups of five PSTs. While creating the groups, female PSTs were randomly assigned to groups of four PSTs by lottery. Due to the low number of male PSTs, a male PST in each group was included in the groups by lottery as the fifth member to ensure a homogeneous distribution in terms of the number of men and women in the groups. Internet access was available in the laboratory environment where the practices were carried out. The PSTs worked in the same groups in all activities, and at least one computer was provided for each group. Within the scope of the study, five activities that were prepared using various sources were implemented via worksheets based on the literature. The activities were: *Wind turbine design*, *Bioplastic production, Water purifier design, Life on Mars* (supported by augmented reality application), and *My Cell Model* (using the

Minecraft education version). These activities were based on the topics of "energy", "compounds", "separation of mixtures", "space technologies" and "cell". The topics were chosen according to the middle school science curriculum (Ministry of National Education [MoNE], 2018) so that the PSTs could adapt the general science curriculum to meet the needs of their future students. Because the PSTs will become middle science teachers after graduation. We made plans so that the PSTs could work in cooperative groups of five for each activity. The instructional process was carried out with the help of worksheets prepared using the literature (Aydın-Günbatar, 2019; BAUSTEM, 2018; Çepni, 2018; Çorlu & Çallı, 2017; Moore et al., 2015; NASA, 2018a; 2018b; 2018c; Wheeler et al., 2014). On the first page of the worksheets, there is a table including sections called "*Professions*", to contribute to creating career awareness and to reveal the importance of interdisciplinary work to solve a problem and "*My Duties and Responsibilities*", which we provide in a cooperative learning environment. All activities begin with the presentation of a knowledge-based life problem. Then, it is continued through six basic sections in the worksheet, each of which consists of multiple sub-sections: (1) *Getting Knowledge*, (2) *Generating Ideas*, (3) *Developing a Product/Solution*, (4) *Improving/Making Changes and Trying Again, (5) Introducing/Sharing Product (Solution)* and (6) *What I Learned during the Process*. The "*Getting Knowledge*" section consists of three subsections: "*What I Know?*", in which students write down what they have known and experienced to reveal their prior knowledge about the problem and possible solution(s). "*What I Want to Research?*", which creates opportunities to generate questions to find solutions and conduct research in order to find answers to these questions. Also, "*What I've Learned*?", which is the section where they will write the answers they found regarding their questions and the new information they learned as a result of their research. The "*Generating Ideas*" section includes guiding questions. For example, "Write down possible all the different ideas you think of" to make students realize that there may be more than one right path, and "Which of the ideas did you decide to use, why?" to make them aware of the limitations and improve decision-making skills. To improve students' engineering skills, the "*Developing a Product (Solution)*" section is carried out through multiple subsections such as *"Design and Make our plan"*, "*Produce and Implement our plan*", "*Test and Record our data*", *"Analyze and Assess our product (solution)"* including guiding questions such "Is your solution successful? Have you encountered any problems? What kind of problems did you encounter?". The part "*Improving/Making Changes and Trying Again*" consists of the subsections of *"Make changes (Redesign) and Test again", "Record our new data" and "Re-evaluate and Assess again"*. For the subsections, there are guiding questions such as “What changes do you plan on your product?*”* and *“*Was your product work?”. The “*Introducing/Sharing Product (Solution)”* section aims to share the product or solution between groups. This part includes the subsections of “*Introduce/Share*” and “*Assess the product between the groups*”. There is a guiding statement such as "Plan how you will promote your product and use your test data to support your claims.". Depending on the type of event, students can promote the product or solution by preparing a commercial film or text, banner, brochure, poster, etc. for marketing purposes. In the "*What I've Learned during the Process*" part, we aimed to have students reflect on the knowledge, skills, and experiences they learned during the activity. We presented the “Let's design a water purification device” activity in detail at a conference focusing on teacher training (Durmaz et al., 2020).

Analysis of Data

Data analysis of the STEM-A questionnaire

Data analysis of the STEM-A questionnaire was evaluated with thematic analysis based on Tezsezen’s (2017) study. To comprehensively conceptualize STEM and STEM education, learners should not only understand the nature of science, but also the nature of technology, the nature of engineering, and the nature of mathematics (Akerson et al., 2018). Hence, grounded on the literature (Akerson et al., 2018; Harlen, 2015), we added the themes of the nature of technology and the nature of engineering to the themes of the nature of science and the nature of mathematics existing other themes in Tezsezen's study. 20 % of the data that were randomly selected were evaluated jointly by two researchers, who reviewed the responses together and discussed them until a 100 % consensus was reached. In cases where a definitive decision could not be made, the opinion of a third science education expert was sought to achieve 100 % consensus. the problems were resolved by including the diversity of researchers, together reviewing and repeating the same process. The rest of the data was evaluated by the second researcher and then the evaluation of the data was reviewed by two researchers and arranged according to the final decision by reaching a common opinion. Themes and definitions are presented in Tables 1 -3.

Table 1 illustrates the themes and definitions of STEM disciplines.

Table 1 Themes and Definitions of STEM Disciplines

Discipline	Themes	Definitions
Science	Nature	Features related to the nature of science
	Function	Function or purpose of science
	Method/process	Scientific method
	Relationship	Relationship between science and other STEM disciplines
	Skill	Scientific process skills
	Physics-Chemistry-Biology	Science is defined as Physics, Chemistry and Biology
Technology	Nature	Features related to the nature of technology
	Function	Function or purpose of technology
	Method/process	Describes the process of technological development
	Relationship	Relationship between technology and other STEM disciplines
	Skill	Skills to develop/use technology
	Technology developers	Identifies who developed the technology
Engineering	Nature	Features related to the nature of engineering
	Function	Function or purpose of engineering
	Method/process	It defines how engineering is done
	Relationship	Relationship between engineering and other STEM fields
	Skill	Required skills for the engineering field
	Production/Product	Engineering is defined only by its products.
Mathematics	Nature	Features related to the nature of mathematics
	Function	Function or purpose of mathematics
	Method/process	Mathematical methods
	Relationship	The relationship between mathematics and other STEM fields
	Skill	Mathematical skills

The themes and definitions of STEM education are presented in Table 2.

Table 2 Themes and Definitions of STEM Education

Themes	Definitions
Relationship between disciplines	Defines both connections between other disciplines, and pedagogical paradigm
Integrity/Integrated structure in disciplines	Regarding the nature of STEM education, it refers to the integrated structure in which the boundaries between each discipline disappear.
Cross-domain collaboration	Describes collaborative work across disciplines
Relation to real life	It expresses the importance of STEM disciplines in solving real-life problems.
Separation between disciplines	Considers each discipline separately
Irrelevant Answers	

Table 3 shows the themes and definitions of how STEM disciplines are included in the texts of Microbiological Corrosion and Radioactive Verbs cases

Table 3 Themes and Definitions of How STEM Disciplines are Included in the Texts of Microbiological Corrosion and Radioactive Verbs Cases

Discipline	Themes	Definitions
Science	Contents	Scientific terms mentioned in the text reading are emphasized.
	Explanation	It is stated that science has a role in scientifically explaining/researching the relevant case or making it more clear to readers.
	Investigations	It defines the role of science in conducting studies on a subject.
	Relationship/Collaboration	Collaboration of other disciplines is noted regarding the case.
Technology	General technology	Technology is superficially discussed or exemplified by a product.
	Process/Technology for research	Technology that is thought to be used in researching issues related to the case is mentioned.
	Relationship/collaboration	It is explained using the relationship between technology and other STEM disciplines or products.
Engineering	Superficial engineering	Very superficial explanations are given about man-made structures, engineering names or specific engineering disciplines in the case (such as chemical engineering).
	Function	The function or purpose of engineering is stated.
	Process	It is stated how engineering is done.
	Relationship/collaboration	Engineering is explained using the relationship between other STEM disciplines or products.
	Skills	Modeling, problem solving, etc. engineering skills are indicated.
Mathematics	Nature of mathematics	Calculations related to the nature of mathematics are expressed as concepts such as numbers and statistical data.
	Skills	Mathematical skills such as data analysis, interpretation and synthesis are expressed in defining the mathematics in the event.
	Relationship/collaboration	Mathematics is explained using the relationship between other STEM disciplines or products.

Data analysis of semi-structured interviews

We analyzed data obtained from semi-structured interviews based on content analysis. Content analysis allows the collected data to be organized, summarized and interpreted by dividing them into smaller categories (Yıldırım & Şimşek, 2021).

Frequency (f) values of the data obtained from both data collection tools were determined by descriptive analysis. Since the PSTs could write more than one sentence while making definitions, the number of frequencies in the themes may be higher than the total number of participants.

Results and Discussions

STEM Awareness

To investigate the PSTs' STEM awareness, STEM-A Questionnaire was employed.

Results from the first analysis group (part 1) of the STEM-A

First stage, the pre and posttest data regarding the definition of STEM disciplines are shown in Table 4.

Table 4 Themes and Frequency Values of the Definitions of STEM Disciplines

Discipline	Themes	f	
		Pretest	Posttest
Science	Nature	3	2
	Function	**20**	**20**
	Method/process	4	2
	Relationship	1	**4**
	Physics-Chemistry-Biology	4	4
Technology	Process	7	**10**
	Function	**25**	24
	Relationship	**-**	**3**
Engineering	Process	3	**13**
	Function	9	**12**
	Relationship	6	**11**
	Production/Product	**13**	5
Mathematics	Nature	**23**	17
	Skill	1	**3**
	Method	2	**6**
	Relationship	4	**12**

From the data in Table 4, it is apparent that in PSTs' explanations regarding the definition of science in both the pretest and posttest, they mostly emphasized the purpose or function of science rather than the nature of science, the characteristics of science, or the inquiry process, or the relationship of science with other STEM+ disciplines in terms of content or context. It can be argued that a few participants gained a slight awareness in favor of the posttest in their perspectives on the definition of science by using the relationship or collaboration between science and other STEM+ disciplines when explaining what science is. Since the STEM activities practiced during the study were based on the science curriculum, science discipline was always taken as the central discipline and other disciplines were integrated into science as a context. For this reason, although we cannot put forward any evidence, the PSTs may have stated more of the functionality/purpose of science in the definition of the science discipline, taking into account the program-related aims of the activities in the posttest.

Regarding the definition of the discipline of technology, as in the definition of science, the majority of participants declared the purpose or function of technology in both the pretest and posttest. This result is not surprising to us, because the technology discipline is integrated into the science discipline as a context in the activities. For instance, technology was integrated with augmented reality in the *Life on Mars* activity and with the Minecraft educational version in the *My Cell Model* activity. As a result, we can say that a difference of understanding has developed in favor of the posttest. While some participants conceptualized the technology discipline, they revealed the development processes of technology and the contribution of other disciplines to this process.

Concerning the definitions of the engineering discipline, the participants mostly defined technology as production or product development in the pretest. When we analyzed posttest data, we found that participants defined the engineering discipline by considering engineering thinking, the engineering design cycle, and collaboration with other STEM disciplines, as well as the function or purpose of engineering. The reason for this positive change in understanding in the posttest may be that the engineering design process was integrated into every activity implemented.

As for the definition of the discipline of mathematics, we can say that the participants showed a positive change in their awareness of the mathematics discipline. The PSTs explained the nature of mathematics by including mathematical skills, mathematical process, and its relationship with other STEM disciplines while conceptualizing the discipline of mathematics.

Based on Table 4, we can argue that the biggest increase in awareness is in the disclosure of the engineering discipline. However, we would like to point out that we did not detect any explanations that meet the themes of the nature of technology and the nature of engineering in the analysis of the pretest and posttest responses of the PSTs. Based on the literature review, Faikhamta (2020) argues that STEM teachers' understanding of the nature of technology and engineering is insufficient. Furthermore, the literature indicates that students have some misconceptions such as "*technology is only artifacts*" and "*engineering design is a single process*" about the nature of technology and engineering, as well as about the nature of science (Kruse et al., 2017).

Overall, as shown in Table 4, increases in favor of the posttest were determined in the relationship theme for the science discipline, in the relationship and process themes in the technology and engineering disciplines, and in the skill, method, and relationship themes in the discipline of mathematics. Evidence of change in favor of the posttest regarding PSTs' awareness of the interrelationship or collaboration of STEM disciplines is presented as an example in Table 5.

Table 5 Change in PSTs' Awareness of the Collaboration/Relationship of the Discipline Fields with other STEM Disciplines

Discipline	Pretest	Posttest	Evidence of change from
Science	"….. expresses the laws of the universe …"	"… It is the most helpful discipline for technology, engineering and mathematics disciplines. …"	function of science to relationship/collaboration between other STEM disciplines
Technology	"… Inventing and building new things to understand life …"	"… It is the discipline where new products or new methods are researched and created by interacting with other disciplines (science, mathematics, etc.) in order to facilitate our daily lives. …"	function of technology to relationship/collaboration between other STEM disciplines
Engineering	"… profession that makes houses, bridges, structures …"	"… Engineering includes math and science related skills. What is done, how it is done and what materials to use are decided by engineers. …"	production/product aspect of engineering to relationship/collaboration between other STEM disciplines
Mathematics	"… numbers and figures. The way we use them …"	"… The mathematics covers the numbers, numbers and the relationship between them that we use in engineering and daily lives."	nature of the mathematics to relationship/collaboration between other STEM disciplines

Second stage, the pre and posttest data regarding the PSTs' definitions of STEM education from part 1 of the STEM-A questionnaire are shown in Table 6.

Table 6 Themes and Frequency Values of the Definition of STEM Education

Themes	f	
	Pretest	Posttes
Relationship between disciplines	5	10
Integrity/Integrated structure in disciplines	8	14
Cross-domain Collaboration	-	8
Relation to Real Life	4	6
Separation between disciplines	-	-
Irrelevant Answers	14	-

Table 6 is quite revealing in two ways: First, neither in the pretest nor in the posttest did any PSTs explain STEM education as the sum of individual disciplines. Second, there is a clear trend of shifting to understanding integrated of STEM. The high number of irrelevant answers in the pretest shifted to other themes in the posttest. Considering the increasing frequency values in favor of the posttest, it can be argued that the PSTs realized the relationship between STEM disciplines and the integrated use of disciplines in STEM education. Comparing with the pretest and posttest data, the following two examples of quotes taken from PSTs' responses regarding the definition of STEM education denote the change in PSTs' awareness of the concept of STEM education:

One PST indicated that:

> *‘‘... To raise awareness among individuals about the dominance of these four concepts over human life. ...’’* (pretest)
>
> *‘‘... To make, design and produce something by using science, technology, engineering applications and mathematics collaboratively (sometimes two, three, sometimes all together). ...”* (posttest)

Another PST said that:

> *‘‘... I've heard it a few times. Lego etc. to teach science. create designs with tools ...’’*(pretest)
>
> *‘‘... In order to improve the problems we may encounter on a daily basis, students are asked to find solutions to this event by using science, engineering, mathematics and technology. It is expected to provide group solidarity behavior by interacting with different disciplines of science ….’’* (posttest)

Based on the data obtained from the first part of the STEM-A questionnaire, it was determined that PSTs' awareness of the relationship between STEM disciplines and the integrated use of disciplines in STEM education showed a positive development in favor of the posttest. Literature studies (Aydın-Günbatar et al., 2021; Radloff & Guzey, 2017; Tezsezen, 2017; Wang et al., 2020) also support the positive effect of STEM applications on PTs' conceptualization of STEM and STEM education. Arslanhan (2019), Aslan-Tutak et al. (2017), and Tezsezen (2017) have also stated that, because of the instructional practices they conducted, the most significant change observed in the participants' understanding of STEM was related to how the integration of STEM disciplines is achieved. We note that there is no apparent consensus among stakeholders on how STEM is conceptualized (Dare et al., 2021).

Results from the second analysis group (part 2) of the STEM-A (2 case studies)

This part includes reading texts on two topics encountered in daily life (*Microbiological corrosion and Radioactive verbs*). To investigate the participants' awareness of STEM disciplines, the question "How are the disciplines of science, technology, engineering and mathematics included in the text you read?" is posed. The data obtained for both cases are given in Table 7.

Table 7 Themes and Frequency Values Regarding the Involvement of STEM Disciplines in the Microbiological Corrosion and Radioactive Verbs Cases

Discipline	Themes	f			
		Microbiological corrosion		Radioactive verbs	
		Pretest	Posttest	Pretest	Posttest
Science	Content	15	16	19	20
	Explanation	10	**14**	2	2
	Research	6	3	-	-
	Collaboration	-	-	6	6
Technology	Specific technology area related to the focused issue	17	**19**	-	-
	General technology	13	6	11	12
	Relationship / Connection	-	**6**	3	**5**
	Process	-	-	14	9
Engineering	Skill	-	-	8	**10**
	Process	2	**6**	-	-
	Specific engineering area related to the focused issue / production	16	6	-	-
	Engineering explanations in a superficial sense	-	-	14	6
	Function	10	**13**	-	-
	Relationship / Connection	1	3	2	**4**
Mathematics	Nature	20	14	22	22
	Skills	9	**14**	4	5
	Realitionship / Connection	1	**7**	4	3

As seen in Table 7, there is an increase in favor of the posttest in the statements of the PSTs stating that the science discipline is included in the content and explanation categories in the Microbiological Corrosion case. For example, one participant commented on the presence of the science discipline in the text: *"... the negative effects of microbiological corrosion on metal and metal alloys have been examined. Examples such as the rusting of iron have been given, and it has been observed that it causes damage in the industry ...*". In the pretest, responses regarding the awareness of the technology discipline in the text included superficial explanations about technology in general. However, in the posttest, it was determined that these explanations were replaced by more specific explanations concerning the technology use in the focused issue and its interaction with other STEM disciplines. For example, *"... the structures that make life easier (pipes, houses, vehicles, ...) are all products* *of technology... However... corrosion and its damages, which are problems in modern industry, are also related to technology. ...* ". Regarding awareness of the discipline of engineering in the text, the theme of Engineering/Production (which includes specific engineering fields like man-made structures or chemical engineering) stood out in the pretest. However, in the posttest, it was observed that the responses shifted towards themes of process, function, and relationship. These themes indicate how engineers manage the process, define their function, and work in coordination with other STEM disciplines, rather than providing general information about the field of engineering. For example, it can be argued that a more detailed explanation is given in the sentences *"... detecting electrochemical reactions...*"; *"... investigating the damages of microbiological corrosion on metal and building materials...*". Regarding awareness of the mathematics discipline in the text, the theme of the nature of mathematics stood out in the pretest. PSTs expressed superficial concepts such as calculations, numbers, and statistical data. However, in the posttest, it was discovered that this theme was replaced by the skill theme. Answers related to data analysis, interpretation, and synthesis were coded under this theme, along with the theme of the relationship with other STEM disciplines. For example; "... *calculation of the change in countries' annual corrosion expenditures, calculation of the damages of microbiological corrosion...*"; *"... expressing the results with numbers and evaluating the effects of the probabilities of the processes with numbers...*".

It is somewhat interesting to note that in this case, the PSTs did not include any explanations regarding the relationship/collaboration of science with other disciplines, the development process of technology and engineering skills, neither in the pretest nor in the posttest. In general, the PSTs explained the subject of corrosion only as chemical corrosion in both the pretest and posttest. Two examples of quoted sentences from the responses given are shown below:

"Corrosion is included in the text as the deterioration of metals and metal alloys with their environment or by electrochemical reaction."

"In the text, how corrosion occurs is explained in relation to chemicals."

Although we cannot put forward any evidence, we can think that the reason for this may be that the topic of corrosion in chemistry courses is explained only with examples of chemical corrosion. In summary, it can be argued that while the pretest in the Microbiological Corrosion case generally showed PSTs' awareness of the nature of science, technology, engineering, and mathematics, their understanding of the functionality and interrelationships among these disciplines and their effects on each other increased in the posttest. In the case of radioactive verbs, no significant difference was detected in the posttest regarding the participants' answers on how the science discipline was involved in reading the case of radioactive verbs. One participant's answer is presented as an example: *"... explaining the formula developed by the mathematics professor by comparing it to particle physics…*". Concerning how the discipline of technology is included, it is noteworthy that there was an increase in the relationship theme in favor of the posttest in the participants' answers. An example of direct quotes from participants' answers is that *"... radioactive decay in this process and this process, its half-life process, is an area that can be followed with technology...*". Regarding the engineering discipline, it is worth noting that there was an increase in the theme of relationship and skill in favor of the posttest in the participants' answers. An example of direct quotes from participants' posttest is given: *"... mathematicians act in line with a plan when applying the formula, they have developed and compare new results with old results...*". Additionally, there was an increase in the participants' answers regarding how the discipline of mathematics was included in the skill category, favoring the posttest. One participant stated such as *''… transforms the phenomenon in physics into certain numbers by looking at its English history …*".

As seen in Table 7, in the case of microbiological corrosion and radioactive verbs, we see that the number of codes belonging to the same themes is different in both the pretest and posttest. There may be several possible explanations for this result. One possible explanation may be the different subject contents, and another may be the content and levels of PSTs' prior knowledge of the subjects. For these reasons, the PSTs may not have been successful in making comprehensive inferences from the texts in both cases. Overall, when considering the case of microbiological corrosion and radioactive verbs in the second part of the STEM-A questionnaire, it can be claimed that although the participants' performance in recognizing interdisciplinary relationships is poor, there is a slight increase in functionality, inter-relationships of disciplines, and awareness of their effects on each other in the posttest, unlike the pretest.

The finding aligns with the previous research conducted by Tezsezen (2017). Given the composition of the chemistry courses within the science teaching program, it can be noted that the allotted number of lesson hours for addressing corrosion and radioactivity topics is relatively low. Consequently, it is plausible to assume that participants may have had limited knowledge about corrosion and radioactivity from both their everyday experiences and chemistry coursework. Pleasants and colleagues (2021) determined in their study with teachers and PTs that the majority of the participants made very superficial conceptual connections between STEM disciplines. For the two cases in this section of the questionnaire, the participants generally associated STEM disciplines mostly with engineering and mathematics disciplines and they had difficulty in associating technology with other STEM disciplines. This finding corroborates the result of Gül (2019), who reported that mathematics and technology disciplines were not included in the STEM lesson and activity plans prepared by PTs. Further, Değirmenci (2020) highlighted the STEM self-efficacy of teachers with low self-efficacy in integrating technology and engineering disciplines was also low. In this context, Aydın-Günbatar et al. (2021) recommended emphasizing the relationship between STEM disciplines and the engineering design process in STEM education practices for PTs to grasp the concept of integrated STEM education.

Views of the PSTs' Regarding the Process of STEM Practices

To reveal the views of the PSTs about the process of STEM practices, we focused specifically on the interviewees' awareness of the applicability of STEM practice. The data obtained are presented in the order of questions in the interview form:

Question 1: In which subjects do you think you can include STEM practices within the scope of science courses in your professional life? Regarding this question, seven of the participants stated that it could be applied in every subject, while three of them claimed that it could not be applied in every subject. Examples of the PSTs' answers to this question are presented below:

> *‘‘... people and the environment. I would use it too... actually, it can be used in many subjects, actually. In fact, science is used in many, many subjects because it is our life itself and because it is everywhere. In all..."*

> *‘‘... It would be very difficult to apply it in biology, for example, our organs and systems, I think these cannot be applied, but there are engineering units in the best force and motion units, for example, they can also be used in engineering applications. In chemistry, substances, properties of substances, acids, and bases can be applied in all of these, but I think I will have the most difficulty in biology... I will have difficulty... I probably cannot apply it in systems at all..."*

The views of participants corroborate previous research. For example, according to the findings of Siverling and colleagues (2017) from their literature reviews, it was claimed that physics and earth science, among the science disciplines, are more commonly involved in

STEM applications, whereas biology is relatively less involved. Similarly, another study expresses that while physical sciences-based integrated STEM instruction has been increasing in recent years, more research is needed in life sciences-based STEM instruction in K-12 classrooms (Anwar et al., 2022).

Question 2: What do you think you would need if you were to use these practices in your professional life? The obtained data by analyzing the answers of the PSTs is shown in Table 8.

Table 8 Answers of the PSTs to the Question "What Do You Think You Will Need if You Were to Use These Applications in Your Professional Life?"

Themes	Codes	f
Professional Competence	Class domination	4
	Preliminary	1
	Time management	4
Method / Experience	Engineering design process experience	3
	Experience integrating technology discipline	2
	Increased STEM activity planning experience	1
	Hands on skills	2
School Environment	Administrator support	**8**
	Colleague (own major/other majors) support	**8**
	Material supply	7
	Laboratory / large area	5
	Ideal class size (Ideal number of students for a class)	2

As in Table 8, we can see the majority of the participants expressed that they may need support and material supplies from the school administration and other teachers when applying STEM education in their professional lives. The findings of our study are consistent with the previous studies. As mentioned in the literature review, administration and collegial support are important factors in teachers' participation in STEM teaching, and one of the main impediments to effective integrated STEM education is the need for materials and resources for both practitioners and students (Dong et al., 2019; Haatainen et al., 2021; Moore et al., 2014a; Navy et al., 2020).

Question 3: In your opinion, what is the key to making STEM practices productive?" or "What does the efficiency of a STEM practice depend on?: Table 9 presents the data obtained from the analysis of the participants' responses.

Table 9. The Answers to the Questions "In your opinion, what is the key that will ensure that STEM practices are effective?" or "What does the efficiency of a STEM application depend on?"

Codes	f
Student's imagination	1
Collaborative work	**5**
Active participation of the student	1
It is a real problem that is meaningful to the student	2
Properly integration of disciplines	1
Giving enough time	3
Correct information acquisition phase	3
Designing the process to enhance creativity	1

In response to Question 3, the majority of participants stated that successful STEM applications depend on the collaborative work of both teachers and students. It is worth noting that this emphasis on collaboration aligns with the results obtained from existing literature, which also emphasize the significance of collaborative approaches in STEM education (Aslan-Tutak et al., 2017; Wang et al., 2020).

Question 4: How do you include other STEM disciplines other than science in your practices? The data obtained from the analysis of the participant responses is displayed in Table 10.

Table 10 Answers of the Question "How do you include other STEM disciplines in your practices?"

Discipline	Codes	f
Technology	Virtual environment to market products	1
	Devices and mobile applications used	**6**
	Simulations	3
	Augmented reality	4
	Virtual reality	1
	Animations	2
	Photo/video shoots	2
	Educational games	1
Engineering	Sketching / drafting	**5**
	Course design for students to work like an engineer	3
	Inventing a product	2
	Getting economically efficient	1
	Material selection	1
	Durable product development	2
Mathematics	Designing activities that develop mathematical competence	**8**
	Matching activities with mathematics in daily life	1

As seen in Table 10, the majority stated that the integration of disciplines can be achieved by using technology, technological devices, and mobile applications, planning design-based applications in engineering, and including activities that will develop mathematical competence in mathematics. For the technology integration, most of the participants expressed that they could integrate the technology discipline by using technological devices and mobile applications. One of the prominent perspectives regarding the discipline of technology in the literature is "*tools and applications used by science, mathematics, and engineering practitioners*" (Ellis et al., 2020). As mentioned in the literature review, various applications, design programs, robotic software, digital probes to collect and analyze data, computer-assisted design (CAD) software, 3-D printers, etc. can be used for technology integration (Moore et al., 2014a; Roehrig et al., 2021). Students can ascertain both the meaning and applications of science, engineering, and mathematics using STEM tools and techniques (Ellis et al., 2020).

Most participants stated that they could integrate engineering into science courses by planning design-based practices. Since applications of mathematics and science are necessary to solve engineering problems, STEM has a natural unifying/connecting role in meaningfully integrating disciplines and learning the content of science, mathematics, and technology (Moore et al., 2014b). According to the literature review, the engineering design process is mostly used in the integration of the engineering discipline. Researchers usually define a problem scenario for engineers as the management of a technology company or a customer task that is a company contract. This scope is compatible with the nature of engineering, as engineers in their real lives design a new product to find a solution to an existing problem, respond to a need, or make changes or innovations to the existing design according to certain criteria. Based on the literature, brainstorming, laboratory activities, and writing activities are mostly used as teaching/teaching methods in the integration of engineering (Arık & Topcu, 2022). Participants stated that they could integrate the discipline of mathematics by including activities that would improve mathematical competence. Mathematically proficient students make better sense of quantities and their relationships in problem situations. According to the literature, the integration of mathematics into integrated STEM education is difficult. It often works in the background as a data measurement and/or data analysis tool, not taken as a conceptual learning goal for mathematical purposes. However, the role of mathematics in an effective mathematics integration should be made clearer. If teachers want to improve students' understanding of scientific phenomena, they should engage their students in mathematical tasks that require high cognitive effort, such as mathematical modeling (Aminger et al., 2012).

Conclusion and Suggestions

This study was designed to determine the effect of STEM education practices on the PSTs' awareness of STEM education and their views on the STEM practicing process.

In the literature review, it was determined that different results were obtained regarding the effect of STEM education or activities on participants' STEM awareness (Aktaş, 2019; Karisan et al., 2019). In the first part of the STEM-A questionnaire, the PSTs' awareness of STEM was examined through their definitions of STEM disciplines and STEM education. Based on the data obtained from the first part of the STEM-A survey, it can be claimed that the explanations provided by the PSTs changed towards recognizing the integrated structure of STEM disciplines after the implementation, and STEM practices had a positive impact on their understanding of the importance of interdisciplinary cooperation in solving problems. In the second part of the STEM-A questionnaire, participants' awareness of STEM was examined through their explanations of how STEM disciplines were included in the two cases presented. The evidence from this study revealed that the participants encountered challenges in understanding the relationship between STEM disciplines. Recent education reforms emphasize STEM education as an interdisciplinary educational approach (National Research Council [NRC], 2014). If PTs can conceptualize STEM education correctly, then their future students could benefit from theirs experiences.

When we examine the PSTs' views about the process of STEM practices, the study has found that generally, the PSTs agree that STEM practices would make a significant contribution to their professional development. While the majority of participants expressed that STEM practices could be implemented in every subject within the science course, there were some participants who mentioned potential difficulties specifically in biology subjects. Further, we found that many PSTs stated that if they were to implement STEM education practices in their professional lives, they would require support from the school administration and their colleagues. Additionally, they anticipated potential challenges in sourcing materials for their STEM activities. The participants in our study highlighted the significance of collaborative work as a key factor for successful STEM applications. Although extensive research has been carried out on integrated STEM instructions, currently, the literature contains differences in how integrated STEM education is implemented or can be implemented (Dare et al., 2021). This study demonstrates the considerable benefits of STEM practices on PSTs' integrated views of STEM.

Although our study has a small sample size and is based on a single case study design, we can say that PSTs' awareness has increased positively towards the integrated structure of STEM, based on the findings of our study. Additionally, the PSTs have demonstrated an understanding of the significance of interdisciplinary relationships and the integrated structure within STEM education. Research indicates that the basis of training a qualified STEM educator is to ensure that they develop the correct conceptual understanding of integrated STEM education (Kelley & Knowles, 2016) and as teachers' content knowledge, experience, and pedagogical content knowledge of STEM disciplines and integrated STEM education increase, their ability to effectively implement integrated STEM education will also improve (Moore et al., 2014a). This study is expected to make a valuable contribution to the existing literature by aiding PSTs in developing awareness and conceptual understanding of STEM education. It also provides an opportunity for PSTs to gain practical experience in implementing integrated STEM education approaches. Considering that what a qualified STEM education is and how it should be implemented is a complex and challenging process (Dare et al., 2019).

Suggestions

We suggest that longer-term studies be conducted to examine PSTs' STEM awareness and knowledge and skills in integrating STEM disciplines. Pedagogical content knowledge of PSTs to integrate STEM practices into their courses in their future professional lives can be investigated in depth. In future studies, it may be beneficial to examine PTs' knowledge and skills in integrating STEM disciplines and their competence in preparing lesson plans for STEM education. Additionally, for PSTs, sample topics that they are more familiar with from their daily lives can be chosen instead of microbiological corrosion and radioactive verb topics to explore the 'experience component' of STEM awareness. Moreover, to develop a common understanding in the field of education, we recommend that conceptual knowledge and processes related to STEM education be explicitly conceptualized, as in the nature of science and views about scientific inquiry.

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Compliance with Ethical Standards

Disclosure of potential conflicts of interest

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CRediT author statement

The second author developed the initial idea and then the authors both designed the study. The first author supervised the thesis study and provided guiding in the preparation of the lesson plans and STEM activities. The second author conducted the STEM activities under the supervision of the first author and collected all data. First author provided expert guidance all of the data analysis and wrote the manuscript.

Research involving Human Participants and/or Animals

This study was carried out taking into account ethical rules. The participants were informed about the study and asked to sign a consent form based on a voluntary basis. An ethics committee report was not required in studies before 2020. The study was approved with the decision number 2 taken at the meeting numbered 34 and dated 17.09.2018 of the Trakya University Institute of Natural Sciences board of directors. The data of the study was collected in the first semester of the 2018-2019 academic year.

STEM Eğitimi Uygulamalarının Fen Bilimleri Öğretmen Adaylarının STEM Eğitimine Yönelik Farkındalıklarına ve Görüşlerine Etkisi

Özet:

Araştırmanın amacı STEM eğitimi uygulamalarının fen bilgisi öğretmen adaylarının STEM ve STEM eğitimi konusundaki farkındalıklarına etkisini ve uygulama sürecine ilişkin görüşlerini incelemektir. Araştırma tek gruplu öntest/sontest zayıf deneysel desende tasarlanmış olup durum çalışması dahil edilmiştir. Çalışma grubunu 2018-2019 eğitim-öğretim yılında Fen Öğretimi Laboratuvar Uygulamaları I dersine katılan 30 öğretmen adayı oluşturmuştur. Katılımcılar uygun örneklem seçimi ve gönüllülük esasına göre belirlenmiştir. Çalışma dokuz hafta süresince yürütülmüş ve beş STEM etkinliği gerçekleştirilmiştir. Nitel veri toplama araçları olarak STEM farkındalık açık uçlu anketi (STEM-A) ön ve sontest olarak kullanılmış ve elde edilen veriler tematik analiz ile değerlendirilmiştir. Öğretimsel uygulamaların sonunda da on gönüllü katılımcı ile yarı yapılandırılmış görüşmeler yapılmış ve elde edilen verilerin analizinde içerik analizi uygulanmıştır. Bulgulara göre, katılımcıların farkındalıklarının olumlu yönde geliştiği ve STEM yaklaşımının disiplinler arası ilişkinin ve bütünleşik yapısının önemini anladıkları ifade edilebilir.

Anahtar kelimeler: Fen bilgisi öğretmen adayı, STEM eğitimi, STEM farkındalığı.

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Research Article

Effect of Algodoo Supported Periodic Table Instruction on Students' Achievements and Perceptions

Hasan ÖZCAN[1], Esra KOCA[2], Davut SARITAŞ[3], H. İlker KOŞTUR[4]

[1] Aksaray University, Faculty of Education, Türkiye, hozcan@aksaray.edu.tr, https://orcid.org/0000-0002-4210-7733

[2] Ministry of National Education, Sehit Mesut Acu Middle School, Türkiye, esra_gk@hotmail.com, https://orcid.org/0000-0001-8994-0397

[3] Nevşehir Hacı Bektaş Veli University, Faculty of Education, Türkiye, davutsaritas@gmail.com, https://orcid.org/0000-0002-5108-4801

[4] Başkent University, Faculty of Education, Türkiye, kostur@baskent.edu.tr, https://orcid.org/0000-0001-8557-4385

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Abstract–In parallel with the development of software technologies, there has been a growing use of useful and accessible simulation tools in education, enhancing the quality of simulations. This study investigates the effect of an activity designed to teach the periodic table on students' academic achievement and explore students' perceptions of the activity. The activity was based on the Algodoo tool, which is primarily used in teaching physics courses. This study employed a convergent parallel design as a mixed-methods research approach. The sample consisted of 31 students (16 males, 15 females) in grade 8, attending a central lower secondary school in a city in the Central Anatolia region of Türkiye. Both quantitative and qualitative data were collected and analyzed. The findings demonstrated that the activity supported by the Algodoo simulation software positively impacted students' academic achievement in learning the periodic table. Furthermore, qualitative data revealed that students had a positive perception of the software in terms of both educational utility and usability. Additionally, students' scientific skills were developed in the designed instructional environment. According to the findings, the Algodoo software could be incorporated into teaching not only macro-level physics but also chemistry courses.

Keywords: Science education, periodic table, Algodoo, simulation.

Corresponding author: Hasan ÖZCAN, hozcan@aksaray.edu.tr

Introduction

At the heart of technology lies its origin in “Techne”, an ancient Greek term denoting the artful craft and creation of all things good. Originally, Techne embodied the essence of craft, invoking skillful artistry. It carries a rich legacy of learning, intertwined with the expertise of craftsmen who preserve and pass down the hidden values, standards, and skills that define their crafts (Hodgkin, 1990). Technology, the embodiment of systematic knowledge in creating and executing tasks, springs forth from the intersection of human interests, desires, and necessities. This pivotal aspect sets it apart from scientific knowledge. Through technology, the scientific understanding aimed at unraveling natural phenomena transforms into practical knowledge for construction and production. Gradually, it starts shaping people's lives, facilitated by advancements in technology. Today, this influence has been explicitly found in education as well, which is one of the most prominent aspects of human life. Although the importance and necessity of the use of technology in education has been emphasized for a long time (Demircioğlu & Geban, 1996; Jonassen & Reeves, 1996; Özcan & Yılmaz, 2019), the Covid-19 pandemic has intensified its importance and necessity in the past year. The published international reports (see Organization for Economic Co-operation and Development [OECD], 2020; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2020; World Bank, 2020) highlight that the pandemic has provided technological opportunities to re-evaluate and re-shape the future of education. The process of the pandemic has already unveiled what existing technological opportunities provide education and enhanced the awareness of and need for innovative technologies that enable distance learning (e.g. mobile applications, web tools, communication media, augmented reality, etc.). This clearly indicates that technology will become a major component of education in the near future. In other words, technology-supported teaching (e.g. computer-assisted instruction, web-based training, etc.) are now a necessity. The use of technology in education is no longer a preference but a basic standard of education regardless of pedagogical approaches being adopted. Therefore, the incorporation of technological tools and facilities into educational settings has been increasingly sought as a standard in education.

Students' personal experiences are of primary importance in science education in particular. Many technologies currently used in education widen students' learning experiences. For instance, through simulations, students can experience events and phenomena that they cannot observe under normal or extraordinary circumstances, such as the pandemic-related restrictions. Simulations are applications that facilitate the experience of events and phenomena through representations of reality and visualizations. Simulations better facilitate the management of learning/teaching settings through not only shaping experience but also re-directing it (Özcan et al., 2020; Reynolds & Anderson, 1991). Studies have shown that simulations are effective in science education in terms of many aspects, such as conceptual learning, academic achievement, and positive attitudes (Bozkurt & Sarıkoç, 2008; Jaakkola & Nurmi, 2008; Jaakkola et al., 2011; Karamustafaoğlu et al., 2005; Rutten et al., 2012; Tanel & Önder, 2010). Simulations have long been used to teach sciences (De Jong & Van Joolingen, 1998; Hakerem et al., 1993). Yet, every day, more useful and accessible, enhanced simulations are becoming available for use in education due to rapid developments in internet and software technologies.

Algodoo

Algodoo is a simulation software used to create simulations for PCs, tablets, smartphones, and smart boards. It typically provides a digital learning platform that simulates the movements of objects that can interact with each other in accordance with Newtonian mechanics by representing the objects in 2D (Euler et al., 2020). The use of Algodoo, which is a cost-free software, is straightforward. It can produce on-screen objects that can be seen in 2D format with only the use of a mouse or touchpad. It can also design physical events (e.g. free fall) and mechanisms (e.g. simple machines). Therefore, teachers and students can easily use the Algoodo (Figure 1). Euler et al. (2020) found that students using Algodoo for the first time in physics class used three different activities: Exploration of the Software Fundamentals, Testing and Contrasting, and Engineering. They reported that students engaged in fruitful debates about physics by using software without any instructions from teachers.

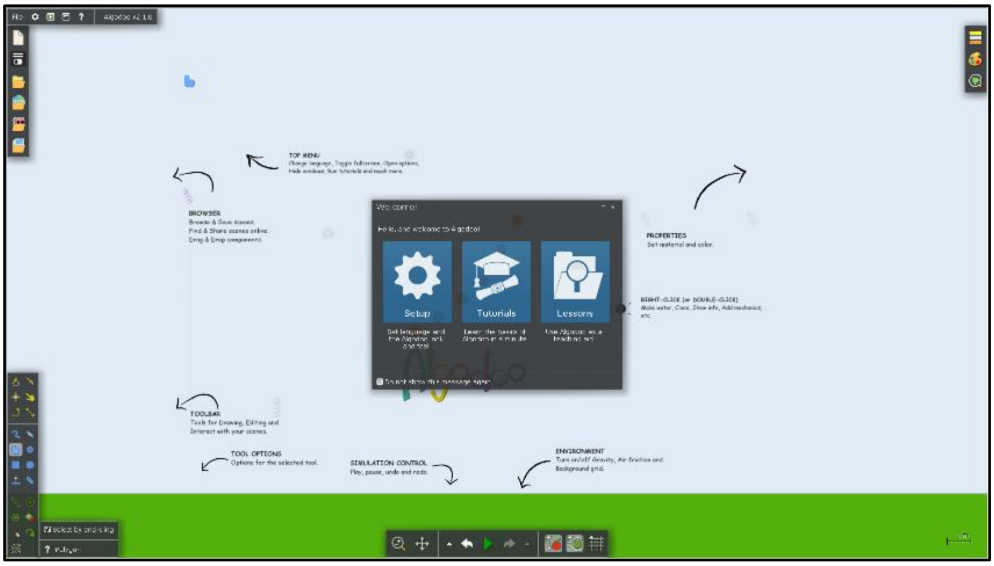

Figure 1 Software Screen and Control Panel

The existing literature proposes that the Algodoo software is primarily used to teach physics courses. Studies have demonstrated that physics education supported by Algodoo contributes to students' learning in a meaningful fashion, to develop science process skills (e.g. developing hypotheses, making inferences, identifying variables, controlling, etc.) as well as creative thinking, and to improve attitudes toward the course subject and motivation toward learning (Akdağ & Güneş, 2018; Cayvaz & Akça, 2018; da Silva et al., 2014; Gregorcic & Bodin, 2017; Hırça & Bayrak, 2013; Siregar et al., 2019).

The extant literature indicates that the Algodoo software is primarily used for teaching physics courses. Research indicates that Algodoo-based physics education enhances students' learning outcomes, fosters scientific process skills (such as hypothesis development, inference, variable identification, and control), promotes creative thinking, and improves attitudes toward the subject and motivation to learn (Akdağ & Güneş, 2018; Cayvaz & Akça, 2018; da Silva et al., 2014; Gregorcic & Bodin, 2017; Hırça & Bayrak, 2013; Siregar et al., 2019). Moreover, since the software has a design-focused approach, it contributes to making sense of the relationship between the STEM subjects of science, technology, engineering and math as required (Şahin, 2018).

Chemical Knowledge System and Periodic Table

As one of the major science subjects, chemistry comprises complex and multi-level knowledge systems. Talanquer (2011) puts forward that the chemical knowledge relevant for teaching comprises three types of knowledge: experiences, theoretical models, and visualizations. Visualizations "encompass the static and dynamic visual signs [e.g. chemical symbols and formulas, particulate drawings, mathematical equations, graphs, animations, simulations, physical models, etc.] developed to facilitate qualitative and quantitative thinking and communication about both experiences and models in chemistry" (Talanquer, 2011, p.187). In the existing literature on chemical teaching, one of the main topics has focused on students' difficulty in making sense of not-experienced, indirect levels of knowledge (e.g. atoms and molecules) and relating them to directly experienced, macro levels (Franco & Taber, 2009; Gilbert & Treagust, 2009; Taber & Coll, 2002; Tarkın Çelikkıran et al., 2019). To tackle this difficulty, it was advocated to use in chemical teaching the models, materials, and applications "illustrating" (visualizing) the micro (Jaber & Boujaoude, 2012). With newer technologies, certain technological applications (e.g. animation and simulation) are also suggested for use in chemical teaching to illustrate scientific knowledge of phenomena that people cannot directly observe through conventional materials (i.e. tangible materials, especially particle models, and analogies and drawings) (Belford & Moore, 2016).

The periodic table is a cornerstone of chemical knowledge and is considered one of the most profound discoveries in the history of chemistry. It provides a fundamental visualization of chemical elements organized according to specific rules. As an icon of chemistry (Wang & Schwarz, 2009), the periodic table is often one of the first topics taught in the discipline. Students are expected to effectively use the periodic table and to be equipped with the necessary skills to make effective predictions and test chemical elements using periodicity (Sarıtaş & Tufan, 2019). Introduction to the periodic system is a part of the 7th grade science education curriculum and falls under the lower secondary level. At this stage, students are introduced to the first 18 elements and their symbols in the periodic system. This instruction typically spans two course hours and provides students with a basic understanding without extensive exploration of the entire periodic table. Furthermore, the periodic system is revisited in the 8th grade science education curriculum (under the subject of periodic system) (MoNE, 2018, p.50). At this level, students discover periods and groups, classification of elements, history of the periodic table, and determination of metals, nonmetals, and metalloids in the periodic table over four course hours. The learning outcomes included in the science curriculum are as follows:

> F.8.4.1.1. Explains how groups and periods are structured in the periodic system. The need for periodic systems and the development of periodic systems are briefly highlighted.

F.8.4.1.2. Classifies chemical elements in periodic systems as metallic, semi-metallic, and non-metallic.

The structuring of periods and, relatedly, the concept of period and certain periodic trends, are taught in relation to the topic of the electron distribution of the atom within the course subject of 'Particulate Structure of Matter' delivered in 7th grade. Hereinafter, the periodic table is structured within indirect phenomena such as the electron distribution of the atom. Hence, it is plausible to employ simulations in the teaching of the subject.

The current body of research on the use of the periodic table in chemical education suggests that conventional tangible materials are mainly employed in curriculum design for experiential studies, particularly in secondary education. These materials comprise either the periodic table itself or its enriched version with other tangible materials (e.g. drawings, natural samples of element compounds, etc.), or parts of the periodic table (e.g. chemical elements purposefully-prepared for gaming and information cards) (Alexander et al., 2008; Bayır, 2014; Bernardo & González, 2021; Erdoğan, 2018; Joaquín et al., 2015; Kavak, 2012; Woelk, 2009). These studies found that such tangible materials contribute to chemical education in terms of permanent learning, motivation, and participation. In addition, Wiediger (2009) investigated the use of technology in the teaching of the periodic table, for which image-editing software was developed and introduced to imitate a periodic table activity supported by a paper-based card sorting game.

The use of instructional technologies in science education has become prevalent in recent years. Simulation offers numerous advantages over traditional materials, especially in chemistry education (Krüger et al., 2022). Simulations provide students with the opportunity to conduct unlimited experiments in a safe environment and receive rapid feedback. Additionally, they can prepare students for laboratory experiments, reinforce concepts in the classroom, and provide experience using instrumental methods that may not be available in the laboratory. However, the periodic system was not investigated in the studies conducted. Studies are generally conducted at the undergraduate level and relate to chemistry laboratory subjects (Li et al., 2022; Wang et al., 2023)

Currently, experiential and applied studies exploring the effectiveness of teaching materials in simulation-based instruction of the periodic table.

Research Aims

Previous studies have suggested that the Algodoo software was used in relation to STEM activities, mostly to physics subjects at the macro level, to develop students' design skills. Studies have shown that it positively affects not only students' academic achievement but also their perceptions and attitudes toward the use of education technologies in science education. However, among them, no studies have focused on chemical teaching. Given that the periodic table is defined within the electron structure of the atom in lower secondary science education, the use of simulations supported by Algodoo could facilitate the teaching of this course subject. Therefore, this study aimed to investigate the effect of an activity, which was designed with Algodoo to teach the periodic table, on students' academic achievement and explore students' perceptions of the activity. The activity design was based on Algodoo, which is predominantly used in the teaching of physics courses.

Method

The study used a convergent parallel design as the mixed-methods research design. Mixed-methods design aims to elicit in-depth information on both quantitative and qualitative aspects of the research topic. The convergent parallel design allows simultaneous collection of both quantitative and qualitative data and allows interpretation of such data following analysis using appropriate methods (Creswell & Plano-Clark, 2018). The quantitative component of the study was conducted through a quasi-experimental design with a pretest–posttest control group. A quasi-experimental design was used to find, if any, significant differences in the relationship between the experimental group (EG) and the control group (CG) in terms of academic achievement. The qualitative component of the study was conducted using the phenomenological design to explore students' perceptions of the Algodoo application.

Sample/Study Group

The sample for the quantitative component of the study consisted of 31 students (16 males, 15 females) from 8th grade, attending one of the central lower secondary schools located in a city in the Central Anatolia region of Türkiye during the fall semester of 2019-2020. Due to pandemic-related limitations, a convenience sampling method was chosen over purposive sampling. Specifically, the groups were two sections of the 8th grade level within the same school. The experimental and control groups consisted of 15 and 16 students. In order to elaborate on the outcomes of the quantitative data and explore the perspectives of the participants, semi-structured interviews were conducted in the experimental group. The sample of the qualitative component of the study consisted of five students (three males and two females) from the experimental group who volunteered to be involved in this component of the research. The design of the study emphasized the participants' experiences and their interpretation of those experiences (Dodgson, 2023). A small sample size was used, as is common in qualitative research, to ensure adequate representation of the participants' experiences (Young, 2018). Data saturation, which provides detailed insights, was also considered. The researchers used purposive or convenience sampling to select participants with specific characteristics or experiences related to the research topic (Gill, 2020). The sample for this study consisted of five volunteer students from the experimental group: three boys and two girls. According to Çokluk, Yılmaz, and Oğuz (2011), the number of participants selected for the interviews depends on the richness and sufficiency of the data. In this case, when the first five interviews were carried out, researchers noticed that the qualitative data collected was sufficient for the analysis. This sample size was sufficient for data collection and analysis.

Data Collection Tools

Quantitative data of this study was collected with the academic achievement test (AAT), and qualitative data was collected with semi-structured interviews (SSI). With the data collection from multiple data sets, it was aimed to enrich the data to be analyzed in this study.

The AAT was developed to analyze learning outcomes of the course subject of the periodic table delivered in 8th grade science education. To design the AAT, a large pool of multiple-choice questions was developed by initially compiling questions on the periodic table that were asked in certain exams prepared by the Turkish Ministry of National Education (MoNE). These examinations included the Public Boarding School Scholarship Exam (PYBS), Placement Test (SBS), Examination for Transition from Primary to Secondary Education (TEOG), and High School Entrance Examination (LGS). Then, the weights of questions to assess the learning outcomes were determined by preparing a table of specifications (see Table 1). In the first version of the test, there were 25 multiple-choice questions used. Three academics specializing in science education and a teacher of science were consulted to assess the scope and convenience of the test for each grade level. Following the expert opinions, the prepared questions were endorsed and found appropriate in terms of both scope and convenience for students of all grade levels. The AAT, which comprises 25 questions, was then tested on a student group of 31 from 9th grade, who had already been taught the course subject. The initial data gathered in this preliminary study were analyzed using SPSS 24.0. Five items were removed from the AAT because item analysis showed that item difficulty indexes and item discrimination coefficients of those five items were at the unacceptable level. Therefore, the final version of the test included 20 items. Examples of the items used in the achievement test are presented in Figure 2.

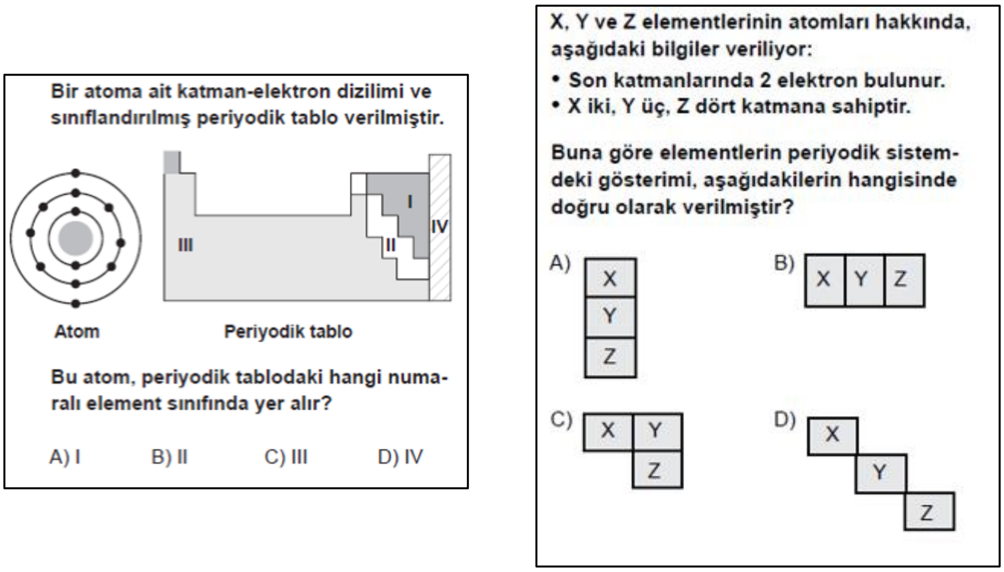

Figure 2 Examples of Items in AAT

Table 1 explains the content of the multiple-choice test used for data collection.

Table 1 Contents of the Academic Achievement Test

Questions	Content
1, 9, 11, 14, and 15	Properties based on the positions of elements in the periodic table
2, 4	The arrangement of elements in the periodic table according to their atomic numbers
3, 5, and 16	Placement of non-metallic and metallic properties in the periodic table
6, 7, and 8	Locating the position of element with and atomic number in the periodic table
10, 12, 17, and 20	Relationship between an element's electron structure and its position on the periodic table
13, 18, and 19	Classifying daily life samples into metals and non-metals according to their properties

Item difficulty and item discrimination indexes were re-calculated after the 20-item AAT was re-tested in the sampling group. Test items had an average difficulty with an item difficulty index between .30 and .675. The items of the test also had an item discrimination index between .375 and .695. To prove the validity and reliability of the final version of the 20-item AAT, the coefficient of internal consistency of KR-20 was calculated for the test. KR-20 was found to be.81, which proves the test was valid and reliable as it exceeds the minimum value of .70 to be considered so.

The SSI schedule explored students' perceptions of Algodoo after they were taught the periodic table supported with Algodoo applications. The SSI consisted of 12 open-ended questions (Appendix 1) and allowed further questions to be added to the interview schedule during the interview (Yıldırım & Şimşek, 2013). Interview questions were prepared in consultation with two academics who specialized in science education. Next, an academic in science was consulted regarding the interview schedule. Following their suggestions, alternative questions were developed, probes were revised, and the interview schedule was finalized.

Implementation

The study was conducted with an experimental group and a control group, and no significant difference was found between the two groups based on the AAT pretest. The teaching of the periodic table was delivered along with an algodoo simulation in the experimental group, whereas curriculum-based suggested activities were followed in the control group through a 5E lesson plan. While both groups were provided with general information about the study, the experimental group was also introduced to the Algodoo software. The operator of the Algodoo simulations was prepared in advance for the simulations to be used in the experimental group and consulted an academic of science for their convenience. The simulations included applications that allow students to create their own atoms, periods, and arrangements while also enabling them to place elements on the periodic table themselves (Appendix 2). After simulations were found convenient, classes were delivered to students in the experimental group by following the phases of the 5E instructional model (i.e. Engage, Explore, Explain, Elaborate, and Evaluate).

Algodoo simulations were used by the operator in the explain phase and by students in the elaborate and evaluate phases (Figure 3). In the control group, the contemporary methods suggested in the science curriculum were followed, and constructivist activities were carried out as the instructional procedure through the 5E strategy. Efforts were made to make the only difference between the groups be the use of the Algodoo simulation. In both groups, the same person as the operator delivered the teaching. Teaching is delivered over eight contact hours . At the end of the delivery, the AAT posttest was administered to the students. In addition, five students from the experimental group were interviewed to understand their perception of Algodoo.

Figure 3 Pictures of the Use of Algodoo Simulations

Data Analysis

The quantitative data gathered from the AAT in this study were transferred to the SPSS 24.0 package. The pre- and post-test score distributions of the experimental and control groups were examined before the data analysis. distribution (Table 2). The Shapiro-Wilk test for distributions indicated that the distribution of pretest scores was normal, whereas the distribution of posttest scores was not normal (Table 2).

Table 2 Data about Distribution Normality

	Shapiro-Wilk		
	X^2	Sd	p
Pretest	.939	31	.078
Posttest	.566	31	.000

The Mann–Whitney U test was used to examine the significance of mean differences between pretest and posttest. Moreover, the Wilcoxon signed-rank test was used to identify the significance of differences by examining the changes between the means of the pretest and posttest of both the experimental group and control group.

The data collected from the semi-structured interviews were first transcribed. Then, they were analyzed through content analysis (Yıldırım & Şimşek, 2013), with which codes and themes, representing the data at best, could be accessed. These themes were then presented in support of direct quotations from interviewees' responses. The students interviewed were anonymized with pseudo-names in those quotations as P1, P2,…,P5.

Findings

Findings regarding the effect of the Algodoo applications used in periodic table instruction on student achievements

Before the study, a pretest was administered to examine the significance of the mean differences between the experimental and control groups. As shown in Table 3, in accordance with the results of the Mann–Whitney U test [U (29) =72.500, p>.05], there was no significant difference between the means of pretest scores of the experimental group ($\bar{X}$=58) and of the control group ($\bar{X}$=66,88).

Table 3 Mann-Whitney U Test Results Regarding the AAT Pretest Scores of the EG and the CG

Group	N	Mean Rank	Rank Sum	U	P
Experimental	15	12.83	192.50	72.500	.057
Control	16	18.97	303.50		

The Mann–Whitney U test was used to examine the significance of mean differences between the posttest means of the experimental group ($\bar{X}$=93) and the posttest means of the control group ($\bar{X}$=83.44). Table 4 shows that there was a significant difference in between, which is in the advantage of the experimental group, and it was found meaningful as a result of the Mann–Whitney U test [U (29) =70.50, p<.05]. The Cohen d value was examined with the posttest means to investigate the influence of the quantity of Algodoo applications and was found to be .70. This value indicates that the quantity of influence is at a medium level (Cohen, 1992).

Table 4 Mann Whitney U Test's Results Regarding the AAT Posttest Scores of the EG and the CG

Group	N	Mean Rank	Rank Sum	U	P	d
Experimental	15	19.30	289.50	70.500	.037	.70
Control	16	12.91	206.50			

The Wilcoxon signed-rank test was used to examine the significance of mean differences between both groups' pretest and posttest means. Table 5 demonstrates that the difference between pretest and posttest means of the experimental group was significant, as shown in the results of Wilcoxon signed-rank test [Z (14) =3.414, p<.01]. Similarly, the difference between pretest means and posttest means of the control group was significant, as shown in the results of Wilcoxon signed-rank test [Z (15) =3.473, p<.01].

Table 5 Wilcoxon Signed-Rank Test Results for the AAT Pretest and Posttest Scores of the EG and CG

Group	Survey	N	$\bar{X}$	SS	Z	p
Experimental	Pretest	15	58.0000	15.90148	3.414	.001
	Posttest	15	93.0000	4.55129		
Control	Pretest	16	66.8750	16.11159	3.473	.001
	Posttest	16	83.4375	18.68321		

Findings regarding students' perceptions of the Algodoo applications used in the teaching of the Periodic Table

Upon content analysis of the SSI data, 2 themes and 9 codes were identified, as shown in Table 6. The theme of educational utility revealed students' perceptions of the Algodoo application during their learning process. The theme of positive features unearthed students' perceptions of the features of an algodoo simulation. The content analysis subsumed codes under two main categories: Educational Utility and Use (Figure 4).

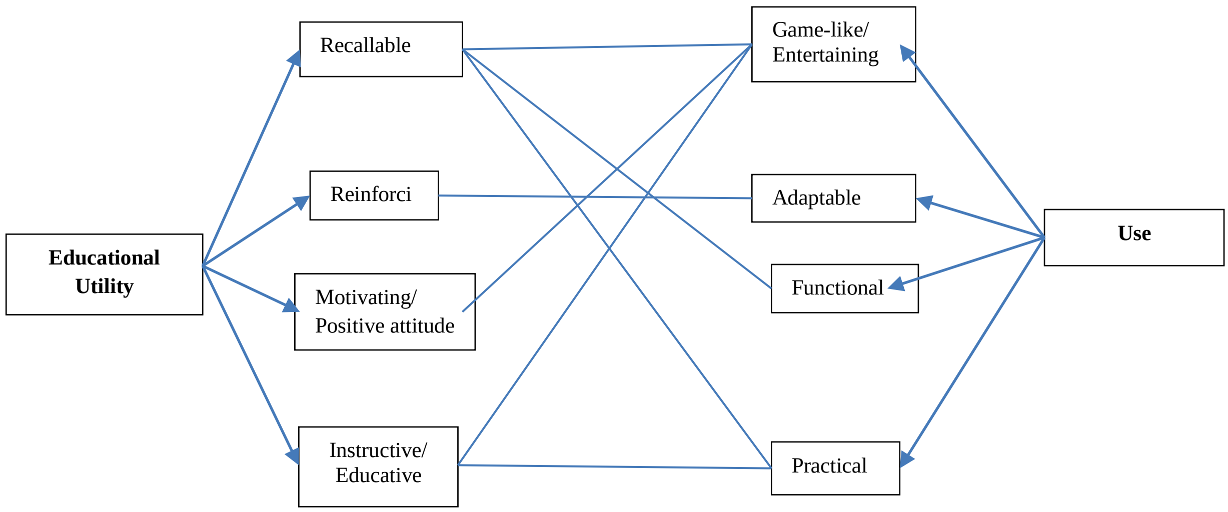

Figure 4 Codes and Categories Identified Through Content Analysis

Figure 4 demonstrates that the participants positively perceived both categories. There seems to be no negative perception regarding the instructional activity supported using the Algodoo software. The relationships the participants made between educational utility and the use of the activity were as follows (Table 6):

Table 6 Themes and Exemplary Quotations

Themes	Exemplary Quotations
Relationship between the instructive/educative aspect of the activity and its practical and entertaining nature	P4: *"I really like that it can be recalled, it is educative, and it is very practical, I mean, you can recall the [necessary] information in a glimpse."* P3: *"The activity was very entertaining. In fact, I have not been able to distinguish the chemical elements so far, but I am much better at it now. The training was really nice; it was good, instructive."*
Relationship between the recallability of the information and the functional, entertaining, and practical use of the activity	P1: *"It was quite educative and recallable. It was designed in a very useful way. I really like it."* P5: "The *application is really good. It stuck in my mind. It was really fun and educative."*
Relationship between reinforcing capacity and re-adaptive capacity of the activity for given information	P2: *"I do not understand some topics in electrical circuits. [Within this activity], electrical circuits can be designed, and I can use them for revisions."* P4: *"It helps us better understand the subject-matter through visualizing it. I wish I had such an activity in an English class as well so that I could understand English words better."*
Relationship between motivating capacity/positive attitude-generating capacity and entertaining capacity of the activity	P1: *"The subject matter has been quite troublesome for me. When I started to use the material and learn about it, I started to grasp the subject matter [better]. We first thought it was boring, but the more we learned about it, the more fun we had."* P3: *"It was entertaining and educative'. First, I thought about not paying attention to the lesson, but then, I realized how nice it was to learn once we progressed."*

Conclusion and Discussion

The research findings of this study evidently demonstrated that an instructional activity supported with Algodoo simulation software was relatively more effective in students' academic achievement in learning the periodic table than contemporary curricular activities. In addition, considering the qualitative research findings, it was found that students have a quite positive perception toward the software in terms of its educational utility and use.

However, although the generalizability of the results of the study conducted using convenience sampling was low, the choice of convenience sampling was deemed necessary for the study. As a matter of fact, this study was conducted with students who had never experienced Algodoo software before. In this context, the findings can be evaluated from different perspectives.

First, it has long been argued that simulations have a positive impact on science education (De Jong & Van Joolingen, 1998; Rutten et al., 2012). Specific to the Algodoo software, the findings of this research support the findings of many other studies with similar samples that used the same software. In fact, Şahin's (2018) recent study carried out with the participation of students in Years 7 and 8 demonstrated that students have positive perceptions of the use of Algodoo for STEM activities to teach simple machines and energy. Similarly, Cayvaz and Akçay (2018) suggested that 7th grade students perceive the Algodoo-supported learning activity as entertaining and that it facilitates the learning process for students during the teaching of work and energy. Moreover, Gül (2019) conducted a similar and experimental study with 7th graders, being taught about light in an activity prepared with the 5E instructional model. Gül found that there is a significant effect of this Algodoo-supported activity on students' academic achievement. Likewise, Özer's (2019) experimental study with Year 6 students learning about power and motion demonstrates that Algodoo-supported activities have a positive effect on students' academic achievement.

Second, the findings of this research were original in terms of the use of the Algodoo software in the teaching of the periodic table. Indeed, in parallel to the rationale for the development of this software, it is used in activities to teach subjects in macrophysics. However, it is not possible to make a sound comparison between the findings of this study and others since there are not any studies focusing on the use of this software in chemical education in general or in the teaching of the periodic table. On the other hand, it is widely discussed in the existing literature that gaming and game-based tangible materials in the teaching of the periodic table have positive effects on students' academic achievement and their attitudes toward the subject (Bayır, 2014; Bernardo & González, 2021; Erdoğan, 2018; Joaquín et al., 2015; Kavak, 2012; Woelk, 2009). Therefore, given that students perceive the software as 'entertaining/game-like', it can be argued that the software has the effect of a game. This argument indirectly supports the existing literature on the teaching of the periodic table through games and gaming. Third, considering that the software is a simulation and enables chemical visualization at the micro and macro levels, such applications as animation and augmented reality seem to be effective for chemical education (Belford & Moore, 2016; Cai et al., 2014). Therefore, the simulation features of the software are conducive to subject-specific teaching. This suggestion similarly supports studies on chemistry and simulations, although indirectly.

Although the Algodoo software is designed for macro phenomena in compliance with Newtonian mechanics, the findings of this study demonstrate that it can also be used in the teaching of other subjects, such as the periodic table. This suitability can be discussed from different perspectives. First, it can be suggested that Algodoo software as a simulation tool is effective in the teaching of the periodic table because it is related to micro-level phenomena such as atomic structure and electron configuration and abstract concepts. Second, the software supports various skills, namely designing, making hypotheses, and testing. (Siregar et al., 2019). Hence, the software is likely to be more effective at upper year-levels, considering that the periodic table, which can be regarded as 'big data' within chemical education, requires skills such as hypothetical thinking and designing newer tables (Sarıtaş & Tufan, 2019). Furthermore, conventional technologies in the teaching of the periodic table are based on games and tangible 3D materials. Thus, various advantages of educational technologies used at upper year levels can also be used in Algodoo and similar similar software programs.

In science education, simulations are suggested for promoting meaningful learning. However, certain hazardous situations may require particular attention. Specifically, the epistemological quality of the information and visualization provided by simulations require particular attention from students (Greca, 2014). Otherwise, chemical illustrations in these types of technological applications can cause conceptual misunderstandings and instructional challenges (Yılmaz & Sarıtaş, 2020). Lastly, considering that Algodoo software enables teachers to organically initiate classroom discussions with minimal intervention on scientific phenomena, laws, and principles (Euler et al., 2020), this software can be quite compliant with pedagogical approaches such as argumentation based on debating in the teaching of other chemistry and science subjects.

In this study, due to pandemic conditions, the sample was limited to 31 individuals. Although the small size of the classes in the sample allowed students to engage in longer Algodoo simulations, it may be considered limited in terms of generalizability. In future studies, new research should be conducted with a larger sample size.

Compliance with Ethical Standards

Disclosure of potential conflicts of interest

There is no conflict of interest to declare.

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CRediT author statement

All authors contributed equally to this work, and therefore, no specific roles are assigned. The order of authorship is as agreed upon by all contributors.

Research involving Human Participants and/or Animals

This study involving human participants has received approval from the [Aksaray University, Social and Human Sciences Research Ethics Committee] and all procedures performed in this study are in accordance with the ethical standards outline.

Algodoo Destekli Periyodik Tablo Öğretiminin Öğrencilerin Başarılarına ve Algılarına Etkisi

Özet:

Yazılım teknolojilerinin gelişimine paralel olarak eğitimde kullanışlı ve erişilebilir simülasyon araçlarının kullanımı daartmıştır. Bu çalışma, periyodik tabloyu öğretmeye yönelik tasarlanmış bir etkinliğin öğrencilerin başarılarına etkisini araştırmayı ve etkinliklerine dair algılarını keşfetmeyi amaçlamaktadır. Çalışmada kullanılan etkinlik, genellikle fizik konularının öğretiminde kullanılan Algodoo'ya dayanmaktadır. Çalışma, bir karma yöntem araştırma yaklaşımı olarak yakınsak paralel deseni kullanmaktadır. Türkiye'nin İç Anadolu bölgesinde bir şehirde bulunan merkezi bir ortaokuldaki 8. sınıf öğrencilerinden oluşan örneklem, 31 öğrenciyi (16 erkek, 15 kız) içermektedir. Bu çalışmanın desenine uygun olarak hem nicel hem de nitel veriler eş zamanlı toplanıp analiz edilmektedir. Bulgular, Algodoo simülasyon yazılımı tarafından desteklenen etkinliğin periyodik tabloyu öğrenmede öğrencilerin akademik başarısını olumlu yönde etkilediğini göstermektedir. Nitel veri bulguları da, öğrencilerin yazılımı eğitimsel fayda ve kullanılabilirlik açısından olumlu bir şekilde algıladıklarını ortaya koymaktadır. Ayrıca tasarlanan öğretim ortamında öğrencilerin bir takım bilimsel becerilerinin de geliştiği gözlemlenmiştir. Bulgular, Algodoo yazılımının sadece makro düzeyde fizik konuları için değil, aynı zamanda kimya konuları için de öğretimde kullanılabileceğini önermektedir.

Anahtar kelimeler: Fen eğitimi, periyodik tablo, algodoo, simülasyon.

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APPENDIX 1

Semi-Structured Interview (SSI) Questions

1. Do you like science courses?
2. How do you feel when takingin a science course?
3. What do you think aboutof the course we covered inon the periodic table?
4. What do you think about materialsthe material related to the periodic table?
5. When you first saw this material related to the periodic table, what did you thinkcame to your mind? Can you explain the material by relating it to the periodic table?
6. What are the positive aspects of this material related to the periodic table?
7. What are the negative aspects of this material related to the periodic table?
8. Can you use this material related to periodic tablesthe periodic table without any help?
9. Would you like to use this material related to the periodic table outsideoutside of class?
10. If you were to design a material related to the periodic table, what typekind of material would you design?
11. Would you like science courses taught usingthe science courses to be taught with other similar materials?
12. Would you like other courses taught usingto be taught with other similar materials like this one??

APPENDIX 2

Experimental Group Sample Lesson Plan

Engage:

After welcoming the students, the teacher reminds them of the elements and their uses they saw in previous years by asking:

Which elements did we observe?

Where were we using them?

What do you know about the characteristics of these elements?

This prompts students to recall their previous knowledge. Then, the teacher presents the periodic table brought to the class and asks why and based on what it was created:

Why and based on what criteria were this periodic table created?

This captures the attention of students. Afterwards, the teacher continued by saying, "Today, we will learn about the periodic table and the classification of elements."

Explore:

After identifying which subject will be learned, the students are asked to perform Activity-1. According to the activity, students are divided into three groups. Each group is given 20 small square papers and a piece of cardboard. Students are asked to create their own periodic tables with the first 20 elements they have learned thus far. It is expected that students will discover that elements are arranged according to their atomic numbers, considering the properties and atomic numbers of the elements.

When students create their own periodic tables, they are asked how they created them. Each student created their own according to different properties. Students are told, "As budding scientists, you have created your own periodic table and classified the elements based on their different properties.

Explain:

Activities in Activity 1 were evaluated. The teacher will explain academic information related to the subject.

Regarding the Periodic Table; In ancient times, people believed that there were four elements: air, water, earth, and fire. Additionally, materials such as gold, silver, tin, copper, lead, and mercury were known, but were not considered elements. However, these elements are now accepted as elements.

Up to 1869, 63 elements had been discovered. Today, there are more than 110 elements, and new elements will be discovered in the future.

The first periodic table was created in 1829 by Johann Dobereiner, who formed triads of elements with similar properties.

In 1862, French scientist Beyuger de Chancourtis arranged elements with similar physical properties in spiral rows.

De Chancourtis placed the known elements around the perimeter of a cylinder in 16 mass units.

Newlands classified elements into 11 groups based on similar physical properties. Elements with atomic weight of eight have similar properties.

Newlands defined this as the LAW OF OCTAVES.

According to this law, any element has properties that are similar to those of the eighth element in the table.

The first to present the periodic table in its current form was German scientist Lothar Meyer and Russian scientist Dmitri Mendeleev.

Mendeleev noticed that when atoms were arranged by increasing their atomic weights, certain properties were repeated.

He arranged elements in rows based on their repeated properties, creating a periodic table with the first two periods having seven elements each and the next three periods having seventeen elements each.

He left some places blank in the periodic table because he believed that there were undiscovered elements.

In subsequent years, a modern periodic table, which we accept it to now, was prepared. In 1911, Ernest Rutherford determined the nuclear charge. Henry Moseley showed that elements were arranged according to their atomic numbers in his studies. Today's periodic table is different from Mendeleev's and others in that it arranges elements not by atomic weights but by atomic number. The most significant change in the periodic table was made by Glenn Seaborg, who added two rows below the periodic table.

Mistakes made in the previous stage are corrected, and the truths are reinforced. Students are asked if they know any other examples, and discussions will take place on these examples.

Sample practices related to the subject in the Algodoo program are shown.

Elaboration:

In this section, the periodic table material prepared in the Algodoo program is presented to the students to help them better understand the information they have learned. Students are allowed to perform activities on Algodoo to reinforce the subject.

Evaluate:

Daily journals are assigned to students regarding the subject.

What did I learn from this activity?

What did I do well? Why?

Which area did I struggle in? Why?

Where did I need help?

In which area should I improve myself?

What strengths and weaknesses do I have?

Acquisition assessment is performed by creating an application on Algodoo.

Engage:

After welcoming the students, the teacher reminds them of the elements and their uses they saw in previous years by asking:

Which elements did we observe?

Where were we using them?

What do you know about the characteristics of these elements?

This prompts students to recall their previous knowledge. Then, the teacher presents the periodic table brought to the class and asks why and based on what it was created:

Why and based on what criteria were this periodic table created?

This captures the attention of students. Afterwards, the teacher continued by saying, "Today, we will learn about the periodic table and the classification of elements."

Explore:

After identifying which subject will be learned, the students are asked to perform Activity-1. According to the activity, students are divided into three groups. Each group is given 20 small square papers and a piece of cardboard. Students are asked to create their own periodic tables with the first 20 elements they have learned thus far. It is expected that students will discover that elements are arranged according to their atomic numbers, considering the properties and atomic numbers of the elements.

When students create their own periodic tables, they are asked how they created them. Each student created their own according to different properties. Students are told, "As budding scientists, you have created your own periodic table and classified the elements based on their different properties.

Explain:

Activities in Activity 1 were evaluated. The teacher will explain academic information related to the subject.

Regarding the Periodic Table; In ancient times, people believed that there were four elements: air, water, earth, and fire. Additionally, materials such as gold, silver, tin, copper, lead, and mercury were known, but were not considered elements. However, these elements are now accepted as elements.

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In subsequent years, a modern periodic table, which we accept it to now, was prepared. In 1911, Ernest Rutherford determined the nuclear charge. Henry Moseley showed that elements were arranged according to their atomic numbers in his studies. Today's periodic table is different from Mendeleev's and others in that it arranges elements not by atomic weights but by atomic number. The most significant change in the periodic table was made by Glenn Seaborg, who added two rows below the periodic table.

Mistakes made in the previous stage are corrected, and the truths are reinforced. Students are asked if they know any other examples, and discussions will take place on these examples.

Elaboration:

In this section, to help students better grasp the information they have learned, a matching activity is conducted on the interactive whiteboard, reflecting different periodic table shapes created by various scientists on the history of the periodic table. The activity includes information on the scientist to which it belongs and according to which rule it was created.

Evaluate:

Daily journals are assigned to students regarding the subject.

What did I learn from this activity?

What did I do well? Why?

Which area did I struggle in? Why?

Where did I need help?

In which area should I improve myself?

What strengths and weaknesses do I have?

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Research Article

Examination of Mathematics Course Contents Related to Proof in the Educational Informatics Network

Fikret CİHAN[1]

[1] Kırklareli University, Vocational School of Technical Sciences, Türkiye,
fikret.cihan@klu.edu.tr, https://orcid.org/0000-0001-8783-4136

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Abstract – This research aims to examine the mathematics course contents related to proof in the Educational Informatics Network. The document analysis method was used in this qualitative research. The data of the study consisted of 35-course contents related to proof in the Educational Informatics Network. These contents were subjected to content analysis. According to analysis results, it has been determined that there isn't enough proof in the contents of the Educational Informatics Network for all grade levels and in all learning domains. Although not in sufficient numbers, the proofs in these contents mostly consist of proofs belonging to the "Geometry" learning domain. The number of proofs in the "Numbers and Algebra" learning domain is limited. It is seen that no proof of the "Data, Counting, and Probability" learning domain is included. In line with the results of this research, it can be suggested to produce more content related to proof suitable for cognitive developments and grade levels by making the most of the potential of technology for all grade levels and all learning domains.

Keywords: COVID-19, distance education, mathematics learning media, online learning, proof teaching.

Corresponding author: Fikret CİHAN, fikret.cihan@klu.edu.tr

Introduction

The World Health Organization (WHO) China Country Office was informed about the “cases of pneumonia of unknown etiology” in Wuhan City, Hubei Province, China, on the last day of 2019 (Ministry of Health [MoH], 2020, p. 5; World Health Organization [WHO], 2020a, p. 1). The number of reported cases from 31 December 2019 to 3 January 2020 was 44 (WHO, 2020a). On 7 January 2020, it was determined that the cause of these cases was a new coronavirus (2019-nCoV) (MoH, 2020; WHO, 2020a). On 13 January 2020, Thailand, on 15 January 2020, Japan, and on 20 January 2020, Korea reported the first cases of imported novel coronavirus (2019-nCoV) from Wuhan (WHO, 2020a). This disease, which affected the whole world in a short time (MoH, 2020; WHO, 2020a, 2023a), was accepted as a Public Health Emergency of International Concern (PHEIC) by WHO on January 30, 2020 (MoH, 2020; WHO, 2023a). On 11 February 2020, WHO Director-General Dr. Ghebreyesus first named the disease 2019-nCoV as **COVID-19** that is the acronym for **CO**rona, **VI**rüs, **D**isease, and 20**19** (MoH, 2020; New Jersey COVID-19 Information Hub, 2020; WHO, 2020b; Yaman, 2021). In the WHO’s daily status reports, the disease was named COVID-19 for the first time in the 12 February 2020 report (WHO, 2020c). The causative virus of the disease was named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (MoH, 2020; WHO, 2020b). In a briefing on March 11, 2020, the WHO Director-General Dr. Ghebreyesus stated that COVID-19, which has been seen in 114 countries, can be characterized as a pandemic (MoH, 2020; WHO, 2020d, 2020e, 2023a). On 5 May 2023, the WHO announced that, although the COVID-19 pandemic wasn’t over, it has ceased to be a global emergency for now and no longer complies with the definition of PHEIC (WHO, 2023a, 2023b). As of July 16, 2023, 6.9 million deaths and more than 768 million confirmed cases have been reported worldwide from this pandemic (WHO, 2023b).

Pandemics have serious social and economic impacts apart from deaths and important health problems (Yaman, 2021). One of the social institutions that has a close relationship with the field of health is the field of education (Yavuz & Toprakçı, 2021). Therefore, a series of measures were taken in the field of education, as in many other areas, to prevent the spread of coronavirus (Alanoğlu & Doğan-Atalan, 2021). Due to the COVID-19 pandemic, which was one of the biggest challenges facing education systems, many countries ended face-to-face education and switched to virtual training and online teaching (Daniel, 2020). The use of digital technology has also come into focus as the pandemic suddenly brought classrooms online around the world (Borba, 2021). Although distance and online learning concepts aren’t new concepts, it has caused a deviation from the traditional classroom teaching model (Schneider & Council, 2021). Globally, 1.6 billion learners have been affected by this process (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2021).

Following the announcement of the first case of COVID-19 in Türkiye on March 11, 2020 (MoH, 2020), the Ministry of National Education [MoNE] announced on March 13, 2020, that primary, secondary, and high school equivalent schools would be suspended for the week of Monday, March 16, 2020 - Friday, March 20, 2020 (Kırmızıgül, 2020; Türker & Dündar, 2020). In addition, MoNE decided to switch to distance education as of 23 March 2020 (Demir & Özdaş, 2020). With this decision, MoNE strengthened the infrastructure of the digital education platform Educational Informatics Network [EIN (EBA)], which has been serving since the 2011-2012 academic year, cooperated it with Turkish Radio and Television Corporation [TRT] and also implemented the psychosocial support system (Özer, 2020). As of August 31, 2020, schools were gradually opened to education with an application similar to the hybrid education model, but due to increasing cases, distance education was started again on November 17, 2020 (Yaman, 2021). Distance education, which was planned to continue until December 31, 2020, was extended until the beginning of the second semester, according to the course of the epidemic (Alanoğlu & Doğan-Atalan, 2021). Finally, as of September 6, 2021, face-to-face formal training was started for all levels, five days a week (Yaşa et al., 2022).

EIN, which has been on the air since 2012, and TRT EIN TV (TRT EBA TV) Primary School, TRT EIN TV Secondary School, and TRT EIN TV High School channels, which were established as a result of the cooperation with TRT, a public broadcaster, were used for education and training during the COVID-19 process (Türker & Dündar, 2020). In addition, distance education was supported with Zoom and similar applications (Balaman & Hanbay-Tiryaki, 2021). During the pandemic, EIN was a reliable meeting point where teachers interacted and communicated with their colleagues and students, and students with their teachers and classmates (EIN, 2020; Yapar et al., 2022). With the COVID-19 pandemic process, the content, functionality, usefulness, and current structure and status of such digital platforms have become even more important (Yapar et al., 2022). Based on this importance, there is an increasing tendency to study EIN-related studies in the literature. In the literature, there are studies examining the views of students (Atasoy & Yiğitcan-Nayir, 2019; Bahçeci & Efe, 2018; Durmuşçelebi & Temircan, 2017), pre-service mathematics teachers (Tuluk & Akyüz, 2019), mathematics teachers (Çavuş & Keskin-Yorgancı, 2020; Kepceoğlu & Ercan, 2019; Tuluk & Akyüz, 2019), and various branch teachers (Türker & Dündar, 2020) about EIN contents and the functionality and use of EIN. Apart from this, there are also studies in the literature that examine and evaluate the mathematics course contents in EIN from various perspectives (Dinler-Esim & Dinç-Artut, 2022; Günbaş & Öztürk, 2022; Poçan & Yaşaroğlu, 2017). For example, Dinler-Esim and Dinç-Artut (2022) examined mathematics course videos in the context of multimedia design principles. On the other hand, Poçan and Yaşaroğlu (2017) examined the contents of mathematics courses according to the seamless learning principles. There are also studies in the literature examining the effects of EIN use on students' cognitive or affective skills in various mathematics topics (Ertem-Akbaş, 2019; Özbey & Koparan, 2020). For example, Özbey and Koparan (2020) examined the effect of EIN-supported mathematics teaching on the motivation, attitude, and achievement of students on equality and equation. Unlike the studies in the literature, this study is aimed to examine the mathematics course contents related to proof in EIN. Like all learning environments, the mathematics learning media has also changed with the COVID-19 pandemic (Bullo, 2021; İlhan & Kırmızıgül, 2022). Distance education during the Covid-19 pandemic period has positively affected the use of digital technologies in mathematics education (Temel & Gür, 2022). How has the teaching of proof been affected by this change? Since proof is an important component of mathematics education and it is needed to improve mathematical understanding as it is at the center of mathematics (Ball et al., 2002); mathematics education researchers recommend that proof become part of students' mathematical experience for all grade levels (Stylianides, 2007). Despite this, mathematics education research shows that proof is very elusive to many students (Hoyles & Jones, 1998). In particular, the results of didactic studies show that students face many difficulties while approaching proving in the classroom (Olivero, 2002). It isn't difficult to foresee that students may experience difficulties in distance education in an area that has such difficulties even in face-to-face education. However, it may be possible to overcome these student difficulties with well-prepared course content. Because of all these reasons, answers to the following research questions were sought in this study:

- For which grade levels are the contents of mathematics courses related to proof are included in EIN?
- What kind of mathematics course contents related to proof are included in EIN?
- Which definitions are included in the contents about proof in EIN and how?

• Which proofs are included in the EIN, in which kind of contents, and how?

Method

This research was conducted following ethical principles and rules. Also, an ethics committee permission was obtained for the research. It was expressed in the official writing of the Kırklareli University Scientific Research and Publication Ethics Board dated 24 July 2023 and numbered E-35523585-302.99-91144 that this research didn't contain any ethical violations.

Research Design

This research included qualitative research, and document analysis (Creswell, 2014; Patton, 2001) was preferred as the research method.

Sampling and Data Collection

In qualitative research, data can be collected from written documents, audio or visual materials (Creswell, 2014). In this context, the data of this research were collected from course contents consisting of written documents, videos, or interactive activities related to proof in EIN.

The sample was determined by the criterion sampling technique, one of the purposeful sampling techniques (Creswell, 2014; Patton, 2001). For this, a set of inclusion and exclusion criteria (Creswell, 2014; Patton, 2001; Yıldırım & Şimşek, 2016) determined by the researcher were applied. The following criteria were determined as inclusion criteria: a) Mathematics course contents related to proof in EIN were included, and b) The contents that can be accessed in the spring term of the 2022/2023 school year were included. The following criteria were determined as exclusion criteria: a) Professional development contents and library contents were excluded, and b) Course contents other than mathematics were excluded.

Considering these criteria, the website of the EIN was accessed from https://www.eba.gov.tr/ (EIN, n.d.) on 25 July 2023. By typing proof in the EIN search engine, the mathematics course contents related to proof in EIN was surveyed (EIN, 2023). As a result of the search, a total of 51 pieces of content were found, including 39-course contents, 1 library content, and 11 professional development contents. Professional development content and library content were excluded from the scope of the study. Since these contents are related to the branches of Physics and Journalism, they were excluded from the scope. Of the remaining 39-course contents, four course contents of Turkish Language and Literature, Civil Law, and Physics were excluded from the scope. Thus, the remaining 35-course contents (EIN, 2023) were examined within the scope of the research. Only one of these contents is teacher-specific and the others are open to the access of both teachers and students.

Data Analysis

The data obtained from 35-course contents were analyzed by content analysis (Creswell, 2014; Julien, 2008; Yıldırım & Şimşek, 2016). In content analysis, data is analyzed in depth and codes are created so that previously non-existent categories or themes would be revealed (Creswell, 2014; Yıldırım & Şimşek, 2016). Qualitative analysis can be digitized in the report (Yıldırım & Şimşek, 2016) by counting the words, categories, or themes repeated in the document in the content analysis (Julien, 2008; Patton, 2001). In addition, one-to-one citations can be included in the reporting of qualitative data (Creswell, 2014).

In this research, in this direction, first of all, what kind of mathematics course contents related to proof in EIN was present for which grade levels were determined and codes were created. Based on these codes, frequency and percentage calculations were made and a cross table was created. Afterward, it was determined which definitions related to proof were included in which course contents and codes were created. The findings were presented with a frequency table. How these definitions are included in the contents were explained with examples and one-to-one quotations. Then, it was determined which proofs are included in which contents and codes were created. Again, the findings were presented with a frequency table. In addition, how these proofs are included in the course contents was explained with examples and one-to-one quotations.

Validity and reliability

In this research, the validity of the research was strived to be ensured by considering the criteria of confirmability, dependability, transferability, and credibility (Guba & Lincoln, 1982; Lincoln & Guba, 1985). The following points were taken into consideration for these criteria (Creswell, 2014; Guba & Lincoln, 982; Lincoln & Guba, 1985; Patton, 2001; Yıldırım & Şimşek, 2016). The contents in the EBA were analyzed impartially by the researcher to provide the confirmability criterion. The dependability criterion was tried to be provided by conducting all the processes of the research (accessing the contents, analyzing the contents, reaching the findings, etc.) in a way that is consistent with each other. The transferability criterion was tried to be taken into account by expressing which contents in the EBA were included in the research and which were excluded. Finally, the credibility criterion was tried to be taken into account by including detailed descriptions and raw data.

The reliability of this study was tried to be ensured by coding reliability (Miles & Huberman, 1994). Since this research is single-authored and the documents analyzed are voluminous, a time-dependent reliability study was conducted (Kirk & Miller, 1986; Yıldırım & Şimşek, 2016). All documents were coded three times by the researcher. The interval between the first two codings is fifteen days, and the interval between the second and third codings is approximately three months. No incompatibility was found between these three codings. In addition, some of the data was coded by another field expert to ensure consistency between coders (Miles & Huberman, 1994).

Findings

First, the findings of the “For which grade levels are the contents of mathematics courses related to proof are included in EIN?” and “What kind of mathematics course contents related to proof are included in EIN?” research questions are included. The frequency and percentage cross-table of the class levels and types of the course contents related to proof in EIN is given in Table 1.

Table 1 Frequency and Percentage Table for Class Levels and Types of Course Contents Related to Proof Included in EIN (EIN, 2023)

Grade level	Document (PDF) (f)	Interactive activity (f)	Video (f)	Total frequency (f)	Percentage (%)
Multi-grade (6th, 7th, 8th) (f)	1	0	0	1	2.86
8th-grade (f)	2	1	0	3	8.57
9th-grade (f)	0	9	12	21	60.00
10th-grade (f)	0	5	3	8	22.86
11th-grade (f)	0	0	2	2	5.71
Total Frequency (f)	3	15	17	35	100.00
Percentage (%)	8.57	42.86	48.57	100.00	*

*Note. *Percentage values in the row and column have been rounded to the hundredths.*

As can be seen from Table 1, there is no course content at the primary school level. It is also observed that there is a very limited number of course contents at the secondary school level (11.43%). Most of the course contents related to proof included in EIN, namely, 21 of 35-course contents (60.00%), consists of 9th-grade course content. This is followed by the

10th-grade course contents with 22.86%. It is seen that there are only 2 (5.71%) course contents belonging to the 11th-grade level.

Again, as seen in Table 1, 17 (48.57%) of the 35-course contents are videos, 15 (42.86%) are interactive activities, and only 3 (8.57%) are PDF documents. These course contents have been prepared by taking into account the learning gains in the mathematics course curriculum (MoNE, 2018a, 2018b, 2018c). Dynamic geometry software has been used in some video and interactive activities. Thanks to the features of dragging, animation, and dynamically adjusting such content, users have the chance to watch and interact repeatedly. 1 PDF document belonging to multi-grade level (6th, 7th, and 8th-grade) is a document specific to teachers. This document is an assessment-evaluation tool for proof methods for students in the special skills development program. Two PDF documents belonging to the 8th grade level are summary documents containing the same small historical pieces (Tzanakis & Arcavi, 2000) about the life of Pythagoras and two different proofs of the Pythagorean Theorem. The 8th grade interactive activity is the interactive activity of one of the proofs in the PDF documents. Elementary education level course contents are limited to these only.

There aren't PDF document in the content of the secondary education level courses. At the 9th-grade level, there are 9 interactive activities and 10 videos, which include definitions and examples of the components of the axiomatic system, and geometric proofs about angles in line, angle, side, and auxiliary elements in the triangle. Two of these videos are broadcast contents of EIN TV (EIN TV, 2020, 2021). There is also 1 video where De Morgan's Laws are proven in the truth table. Finally, there is 1 video with mathematical proofs to related multiplication and division operations in root numbers. At the 10th-grade level, there are 4 interactive activities and 2 videos with geometric proofs about rhombuses, parallelograms, trapeziums, and polygons. In addition, there are 1 video and 1 interactive activity with mathematical proofs about the roots of quadratic equations at the 10th-grade level. At the 11th-grade level, there are only 2 video contents. These two proofs also belong to trigonometry. The contents of the 12th-grade given within the scope of the Basic Proficiency Test [BPT] Mathematics course is a repetition of the topics of the previous grade levels. For example, the topic of "Propositions and Compound Propositions" of the 9th-grade is repeated within the scope of the 12th-grade BPT mathematics course.

Third, the findings of the "Which definitions are included in the contents about proof in EIN ? and how" research question is included. The frequencies of the definitions included in the contents are presented in Table 2.

Table 2 Frequency Table of the Definitions Included in the Course Contents Related to Proof in EIN (EIN, 2023)

Grade level	Learning domain	Sub-learning domain	Definitions	Interactive activity (f)	Video (f)	Total frequency (f)
9	Numbers and Algebra	Logic	Term	2	2	4
			Undefined term	1	1	2
			Defined term	1	1	2
			Definition	2	1	3
			Axiom (Postulate)	2	2	4
			Theorem	2	2	4
			Proof	1	2	3
			Hypothesis	2	1	3
			Conclusion	2	1	3
			Proposition	0	1	1
			Open proposition	0	2	2
			Conditional proposition	0	1	1
			Entailment	0	1	1
			Double entailment	0	1	1
			Quantifiers	0	1	1
			Truth set (Solution set)	0	1	1
			Negative of the open proposition	0	1	1

Note. While no definition is included in some contents, more than one definition is included in some contents.

As can be seen from this table, the definitions given in the contents related to proof in EIN are the definitions of the concepts belonging to the “Propositions and Compound Propositions” topic of the “Logic” sub-learning domain of the “Numbers and Algebra” learning domain in 9^{th}-grade. Again, as can be seen from the table, the definitions of the concepts of “term”, “axiom (postulate)”, and “theorem” are the most common definitions in the contents related to proof in EIN. These are followed by the concepts of “definition”, “proof”, “hypothesis”, and “conclusion”.

From this point of view, it is seen that the definitions of the components of the axiomatic system, such as undefined term, defined term, definition, axiom (postulate), proposition, theorem, and proof are included in the course contents in EIN. However, it is seen that the definitions of components such as false propositions, disproof, lemma, and corollary aren’t included in these 35-course contents. In addition, it is seen that the concepts given above have been defined by considering the criteria of being a definition. These definitions have been defined following the axiomatic structure and hierarchy. In addition, the necessary and sufficient features of the definitions have been given most economically. A specific example would be the definition of the axiom. The definition of axiom was defined as “Propositions whose truth is accepted and don’t need to be proven are called the axiom” in the broadcast content on EIN TV (EIN TV, 2021, 22:03-22:14). In this definition, the concept of axiom is built on the concept of proposition following the hierarchical structure. In addition, all the features of the concept of axiom are given in a sentence most shortly.

These definitions have been given directly in the videos. This information is intended to be reinforced in interactive activities. For example, definitions of some of these concepts have been given in interactive activities. However, which concept a definition was referring to has been left blank. Users are asked to write which concept a definition was related to in these blanks. Users have a chance to interact more with control and retry buttons. In another example, in hypothesis and conclusion examples, a theorem has been given and it is aimed for users to be able to distinguish the hypothesis and conclusion of this theorem.

Finally, the findings of the "Which proofs are included in the EIN, as what kind of contents and how?" research question is included. The proofs at the 8^{th}, 9^{th}, 10^{th}, and 11^{th}-grade levels are tabulated separately. The frequency table of the proofs at the 8^{th} grade level is presented below.

Table 3 Frequency Table of Proofs Included in 8^{th}-Grade Level Course Contents in EIN (EIN, 2023)

Grade level	Learning domain	Sub-learning domain	Proofs	Document PDF (f)	Interactive activity (f)	Video (f)	Total frequency (f)
8	Geometry and Measurement	Triangles	The Pythagorean Theorem has been proven.	2	1	0	3

As can be seen from Table 3, the proofs at the 8^{th}-grade level in EIN are the proofs of the Pythagorean Theorem. Two PDF documents and an interactive activity about the Pythagorean Theorem are included in the "Triangles" sub-learning domain. Two of the many proofs of the Pythagorean Theorem (Nelsen, 1993) are included in these contents. While making these proofs, dynamic geometry software has been used. One of these two proofs is featured in both the video and the interactive activity. In the video and interactive activity, a right triangle with leg lengths a and b unit and hypotenuse length c unit has been given. A square has been formed on each side of this right triangle. And after, it has been proven that the sum of the areas of the small two squares formed by the legs equals the area of the large square formed by the hypotenuse, that is, $c^2 = a^2 + b^2$. In addition, it can be observed that even though the areas of the squares change when the corners of the triangle are dragged by the user in the interactive activity, this equality doesn't change. Then, the visual proof of this theorem is given. A similar 8th-grade visual drawn in GeoGebra, which is accessed from https://www.geogebra.org/ (GeoGebra., n.d.), is given below.

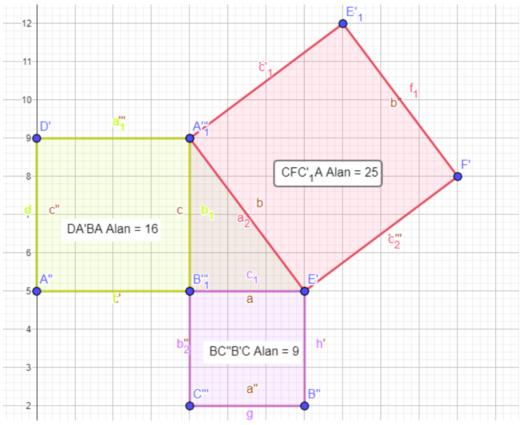

Figure 1 Any Proof of the Pythagorean Theorem with GeoGebra

In Figure 1, the relationship between the sides of the triangle, namely the Pythagorean Theorem, is easily seen from the relationship between the areas of the squares. Similar visual proofs are also included in the 8th-grade (Peker, 2021) and 9th-grade (Ayık, 2021a) textbooks. The frequency table of the proofs at the 9th-grade level is presented below.

Table 4 Frequency Table of Proofs Included in 9th-Grade Level Course Contents in EIN (EIN, 2023)

Grade level	Learning domains	Sub-learning domains	Proofs	Interactive activity (f)	Video (f)	Total frequency (f)
9	Numbers and Algebra	Logic	De Morgan's Laws have been proven.	0	1	1
		Equations and Inequalities	The equality $\sqrt[n]{a \cdot b} = \sqrt[n]{a} \cdot \sqrt[n]{b}$ has been proven.	0	1	1
			The equality $\sqrt[n]{\frac{a}{b}} = \frac{\sqrt[n]{a}}{\sqrt[n]{b}}$ has been proven.	0	1	1
9	Geometry	Triangles	It has been proven that the corresponding angles in a transversal of parallel lines are congruent.	1	0	1
			It has been proven that the alternate interior angles in a transversal of parallel lines are congruent.	1	0	1
			It has been proven that the alternate exterior angles in a transversal of parallel lines are congruent.	1	0	1
			It has been proven that the opposite interior angles in a transversal of parallel lines are supplementary.	1	0	1
			It has been proven that the opposite exterior angles in a transversal of parallel lines are supplementary.	1	0	1
			It has been proven that the sum of the measures of the interior angles of a triangle is 180°.	1	1	2
			It has been proven that the sum of the measures of the exterior angles of a triangle is 360^{0}.	0	1	1
			It has been proven that the sum of measures of two interior angles in a triangle is equal to the measure of non-adjacent exterior angles to these angles.	1	0	1
			The Interior Angle Bisector Theorem has been proven.	1	0	1
			It has been proven that if a point is on the bisector of an angle, then the point is equal distance from the sides of the angle.	1	0	1
			It has been proven that the centroid of triangles is the intersection of the medians.	0	1	1
			It has been proven that the centroids of triangles are at $\frac{2}{3}$ of the distance from the vertices to the mid-point of the sides.	0	1	1
			The Pythagorean Theorem has been proven.	1	2	3
			Euclid's Theorem has been proven.	0	1	1
			It has been proven that a point equal distance from the sides of an angle is on the bisector.	1	0	1
			It has been proven that in isosceles triangles, the bisector between the congruent sides cuts the opposite side perpendicularly.	1	0	1
			It has been proven that in equilateral triangles, each vertex angle bisector is the perpendicular bisector of the opposite sides.	1	0	1
			The Basic Proportionality Theorem has been proven.	0	1	1
			The Converse of Basic Proportionality Theorem has been proven.	0	1	1

As can be seen from Table 4, the proofs included in the EIN mostly belong to the 9th-grade level topics. While most of these proofs are related to the “Geometry” learning domain, proofs related to the “Numbers and Algebra” learning domain are also included. De Morgan’s Laws have been proven in the “Logic” sub-learning domain of the “Numbers and Algebra” learning domain. The equations $(p \vee q)' \equiv p' \wedge q'$ and $(p \wedge q)' \equiv p' \vee q'$, found by Augustus De Morgan (1806-1871), one of the founders of symbolic logic, have been proven by a truth table. These proofs can also be found in the 9th-grade textbooks (Ayık, 2021a; Gökbaş, Kaleci, Mutluoğlu, & Ballı, 2022; Ulualan, 2021). In addition, in the “Equations and Inequalities” sub-learning domain of the “Numbers and Algebra” learning domain, proofs about multiplication and division operations in root numbers with equal root degrees are included. These proofs in EIN are similar to the proofs in textbooks (Ayık, 2021a; Ulualan, 2021). In the “Triangles” sub-learning domain, there are proofs related to the topics “Basic Concepts of Triangles”, “Equality and Similarity in Triangles”, “Auxiliary Elements of Triangle”, and “Right Triangle and Trigonometry”.

As can be seen from the table, the proof that is mostly included in the course contents (f=3) is the proof of the Pythagorean Theorem, as it is at the 8th-grade level. Apart from that, it has been proven both in the video and in the interactive activity that the sum of the measures of the interior angles of the triangle is 180°. There is a visual proof of this theorem in the video. In this proof, the three interior angles of the triangle are folded to form a straight angle. A similar proof is given in Figure 2.

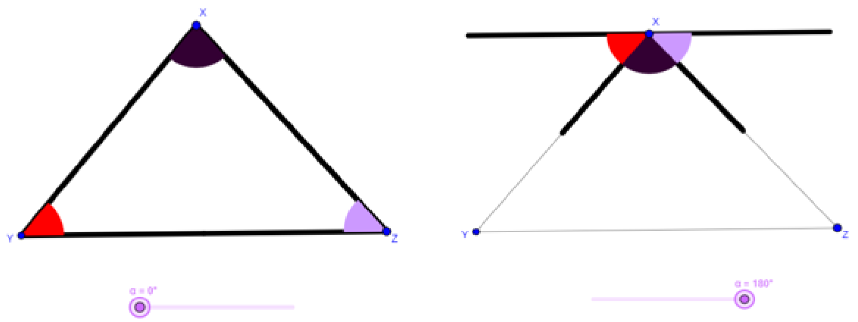

Figure 2 Any Proof with GeoGebra that the Sum of the Measures of the Interior Angles of a Triangle is 180°

The settings of the slider in the horizontal position, which is defined in terms of angle in Figure 2, are set as minimum=0°, maximum=180°, and increment=1°. It can be seen that the three interior angles of the triangle form a straight angle when the slider is dragged from 0° to 180°. The frequency table of the proofs at the 10th-grade level is presented below.

Table 5 Frequency Table of Proofs Included in 10th-Grade Level Course Contents in EIN (EIN, 2023)

Grade level	Learning domains	Sub-learning domains	Proofs	Interactive activity (f)	Video (f)	Total frequency (f)
10	Numbers and Algebra	Quadratic Equations	The relationship between the discriminant and the roots of quadratic equations has been proven.	0	1	1
			Root formulas of quadratic equations have been proven.	0	1	1
10	Geometry	Quadrilaterals and Polygons	It has been proven that the sum of the measures of the exterior angles of convex polygons is 360^0.	1	1	2
			It has been proven that consecutive angles in rhombuses are supplementary.	1	0	1
			It has been proven that opposite angles in rhombuses are congruent.	1	0	1
			It has been proven that diagonals in rhombuses are bisectors.	1	0	1
			It has been proven that in rhombuses, the diagonals intersect each other perpendicularly.	1	0	1
			It has been proven that opposite sides of parallelograms are congruent.	1	0	1
			It has been proven that the opposite angles of parallelograms are congruent.	1	0	1
			It has been proven that the diagonals of parallelograms are angle bisectors.	1	0	1
			It has been proven that consecutive angles in parallelograms are supplementary.	1	0	1
			It has been proven that the mid-segment of a trapezium is parallel to the bases.	1	0	1
			It has been proven that two adjacent angles between parallel sides in a trapezium are supplementary.	1	0	1
			It has been proven that the mid-segment length of a trapezium is equal to half the sum of the lengths of its parallel bases.	1	0	1
			It has been proven that the diagonals of a trapezium divide each other at the same rate.	1	0	1
			It has been proven that the trapezium is isosceles when the adjacent angles on the same base are congruent.	1	0	1
			It has been proven that the trapezium is isosceles when the diagonals divide each other into congruent line segments.	1	0	1

As can be seen from Table 5, proofs related to the "Geometry" learning field are mostly included at the 10th-grade level in EIN. Apart from this, proofs related to the “Numbers and Algebra” learning domain are also included. The relationship between the discriminant of quadratic equations and their roots, and accordingly, the root formulas have been proven by using real-life problems in the “Quadratic Equations” sub-learning domain of the “Numbers and Algebra” learning domain. It have been proven that for the equation $ax^2 + bx + c = 0$ when $a, b, c \in R$ and $a \neq 0$, if $\Delta < 0$ there is no real root of the equation, if $\Delta = 0$ there is a double real root of the equation and the formula is $x_1 = x_2 = -\frac{b}{2a}$, and if $\Delta > 0$ the equation has two different real roots and its formulas are $x_{1,2} = \frac{-b \pm \sqrt{\Delta}}{2a}$ (Ayık, 2021b; MoNE, 2018b, 2018c; Ulualan, 2019). Proofs about the topics of “Polygons” and “Special Quadrilaterals” are included in the “Quadrilaterals and Polygons” sub-learning domain. It is seen that the proofs about the rhombuses, parallelograms, and trapeziums, which are special quadrilaterals, are included. As can be seen from the table, both the video and the interactive activity are included in the proof that the sum of the measures of the exterior angles of convex polygons is 360^0. A well-known algebraic proof, which is also included in 10th-grade textbooks (Ayık 2021b; Ulualan, 2019), is included in the video. The proof is started with the fact that the sum of the interior angles and exterior angles of n genes is $n \cdot 180^{\circ}$. It is also known that the sum of the interior angles of n genes is $(n-2) \cdot 180^{\circ}$. When the subtraction is done, $n \cdot 180^{\circ} - (n-2) \cdot 180^{\circ} = n \cdot 180^{\circ} - n \cdot 180^{\circ} + 360^{\circ} = 360^{\circ}$ is found. Thus, it has been proven that the sum of the measures of the exterior angles of n genes is 360. In the interactive activity, a visual proof of this theorem is included. In the interactive activity, users are asked to determine n corner points in the area reserved for visual proof. To complete the polygon, it is instructed to click on the first point determined, as in some dynamic geometry software. Thus, a polygon is formed, the sides of which form rays according to the number of points determined by the user. The exterior angles of the resulting polygon have been labeled. Users are then asked to drag the slider down. When the slider is dragged to the bottom, all exterior angles gather around a point and form a complete angle. It is possible to test this for all desired convex n genes. From this, it is possible to say visually that the sum of the measures of the exterior angles of any convex n gene is 360°. A similar proof for a convex pentagon is given in Figure 3.

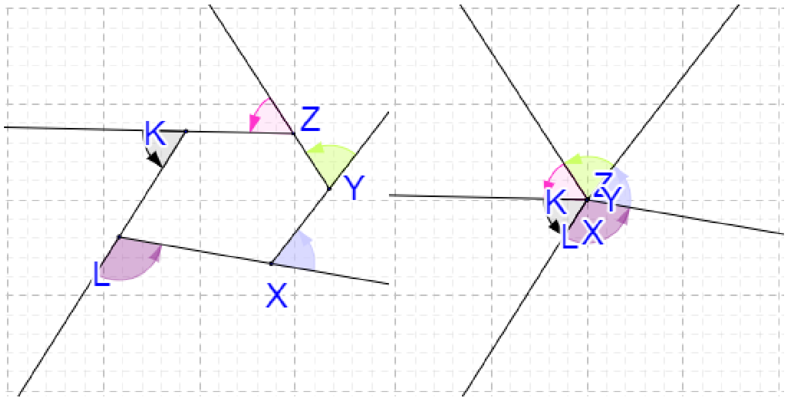

Figure 3 Any Proof with GeoGebra that the Sum of the Measures of the Exterior Angles of A Convex Pentagon is 360°

In Figure 3, it is seen that the exterior angles of a convex pentagon form one complete angle when the slider is moved. The frequency table of the proofs at the 11th-grade level is presented below.

Table 6 Frequency Table of Proofs Included in 11th-Grade Level Course Contents in EIN (EIN, 2023)

Grade level	Learning domain	Sub-learning domain	Proofs	Interactive activity (f)	Video (f)	Total frequency (f)
11	Geometry	Trigonometry	The Law of Cosines has been proven.	0	1	1
			The Law of Sines has been proven.	0	1	1

As can be seen from Table 6, only two proofs are included at the 11th-grade level in EIN. These proofs are proofs related to the "Trigonometric Functions" topic of the "Trigonometry" sub-learning domain of the "Geometry" learning domain. Proofs of Cosines Law and Sines Law are given in one video each. The Cosine Law has been proven by utilizing the real-life problem. In addition, the Sines Law has been proven by associating a triangle and the circumcircle of this triangle.

Conclusions, Discussions, and Suggestions

There are only 35-course contents related to proof in the EIN. It can be expected that this platform, which includes mathematics contents from elementary school to high school, will include more content about proof, which is an important component of mathematics education and is necessary in teaching every subject of mathematics. These course contents are mostly at the 9th-grade level. Contents related to proof are very limited in number until the 9th-grade of secondary education. There is no course content at the primary school level related to proof. The number of contents for the middle school level is also very limited. The number of proofs at the 11th and 12th-grades about proof in the EIN is also very limited. Because it is seen that there is no proof in the EIN regarding most subjects of these grade levels. Proof should be at the center of mathematics teaching for all grade levels (Ball et al., 2002). Accordingly, it can be recommended to produce contents suitable for the class level and cognitive development of students from the first grade of primary education to the last year of secondary education in EIN. By considering the changes in the meaning of proof as the individual matures from childhood to adulthood (Tall et al., 2012), the idea of proof in the contents produced can be expected to deepen.

Considering all grade levels, it is seen that no proof is included in the learning domain of the "Data, Counting, and Probability". It is seen that a very limited number of proofs are included in the "Numbers and Algebra" learning domain. Considering the time and subject weight allocated to the learning domain the "Numbers and Algebra" in the curriculum (MoNE, 2018a, 2018b, 2018c), it is clear that the proofs included in EIN and presented in the tables in the findings are not sufficient for this learning domain. In this learning domain, which has a very broad subject content, only including proofs related to logic, equations and inequalities, and quadratic equations can be seen as a limitation. When all grade levels are considered, it is seen that proofs are given more place in the "Geometry" learning domain. Similarly, in the 9th-grade textbooks taught in Anatolian and Science High Schools in the 2022-2023 academic year (Ayık, 2021a; Gökbaş et al., 2022; Ulualan, 2021), the most proof has been made in the "Geometry" learning domain (Cihan, 2023). Although most learning gains in the 2018 high school mathematics curriculum have been allocated to the learning domain of the "Numbers and Algebra" (Cihan & Akkoç, 2023; MoNE, 2018b), it can be considered as a deficiency that there isn't enough proof in the EIN about the topics in this learning domain. It is also thought-provoking that no proof is included in the "Data, Counting, and Probability" learning domain. The course contents in the EIN have been prepared by taking into account the learning gains in the mathematics curriculum. However, it is seen that enough content isn't produced for every learning gain in every learning domain. From this point of view, it can be recommended to produce at least one written document, at least one video, and at least one interactive activity for each learning gains in each learning domain in terms of content richness. It shouldn't be overlooked that interactive activities on digital platforms can serve as a process-oriented and constructivist approach to proof teaching. In process-oriented proof teaching, students in the role of active learners reach proof by doing it in the process (Yoo, 2008). Similarly, proof isn't presented as a product in interactive activities, the student reaches proof by interacting. Moreover, in interactive activities, students have the opportunity to make mistakes, see their mistakes and correct them.

Geometric proofs may require skills that are difficult to learn (Wong et al., 2011). For example, geometric proofs may require the use of shapes, transformations, diagrams, and inferences (Tall et al., 2012). Therefore, geometric proof teaching differs from mathematical proof teaching (Cihan, 2019). Also, dynamic visual proofs may be more effective than algebraic proofs for proof teaching (Štrausová & Hašek, 2013). At this point, the results of studies reporting the benefits of dynamic geometry environments for teaching geometric proof can be considered (Christou et al., 2004; Hoyles & Jones, 1998; Olivero, 2002). Dynamic geometry software has important functions for dynamically observing, discovering, generalizing, and proving any geometric feature (Özdemir-Erdoğan et al., 2020). By dragging the concrete object, users can interact with a dynamic figure where they can internalize abstract geometric ideas (Wong et al., 2011). It can be suggested that these potentials of dynamic geometry software be utilized more in proof-related videos and interactive activities.

The definitions included in the contents related to proof in the EIN are the definitions of the concepts belonging to the "Logic" sub-learning domain in 9th-grade. One of the learning gains aimed at students in the "Logic" sub-learning domain is "Explains the concepts of definition, axiom, theorem, and proof" (MoNE, 2018b, s. 18; MoNE, 2018c, s. 17). Therefore, definitions of these concepts are included in both video and interactive activities in EIN. It is seen that the definitions of the components of the axiomatic system such as undefined term, defined term, definition, axioms (postulate), proposition, theorem, and proof are included in the EIN, but the definitions of components such as a false proposition, disproof, lemma, and corollary aren't included. The components whose definitions are included and not included in the 9th-grade textbooks (Ayık, 2021a; Gökbaş et al., 2022; Ulualan, 2021) also agree with these results (Cihan, 2023).

Both the ebola, swine flu, bird flu, HIV/AIDS, MERS, SARS, and COVID pandemics seen in the last thirty years and the agreement of experts that new pandemics will emerge in the future also require preparation for the next pandemics (Öztek, 2020). The development of the contents of the EIN, which started to be used in 2012 and whose use and importance increased with the pandemic (Türker & Dündar, 2020; Özer, 2020), has now become an essential situation for every course. The same is true for higher education. In this context, it has been suggested in the literature for the Council of Higher Education to develop a national digital education platform that can be used in all universities in Türkiye (Durak et al., 2020). The best solution in extraordinary processes such as pandemics is distance education (Balaman & Hanbay-Tiryaki, 2021). Also, distance education platforms can also be used to supplement face-to-face education.

It may be thought that it is difficult for students to learn proof in the digital learning environment. However, having more than one access to course contents in EIN is among the advantages of EIN (Alanoğlu & Doğan-Atalan, 2021). The ability to watch videos related to proof more than once and to perform proof activities interactively by the user repeatedly can contribute to the teaching of proof. Because of all these, it can be predicted that increasing the quantity and quality of the contents related to proof may be beneficial in terms of teaching proof.

Suggestions regarding the aspects that teachers find lacking in EIN are available in the literature (Alanoğlu & Doğan-Atalan, 2021; Demir & Özdaş, 2020; Türker & Dündar, 2020; Yapar et al., 2022). EIN development studies can be carried out by taking these suggestions into account. In this study, the current situation regarding the proof has been revealed and suggestions have been made to EIN developers. It can be thought that these suggestions may be useful for teaching effective proof in online learning environments.

Compliance with Ethical Standards

Disclosure of potential conflicts of interest

No conflict of interest.

Funding

No payments or scholarships have been received from any institution for this study.

CRediT author statement

This study was a single author and all processes of this research were carried out by the responsible author in accordance with ethical rules.

Research involving Human Participants and/or Animals

This research did not involve human participants and/or animals. This research was conducted following ethical principles and rules. Also, an ethics committee permission was obtained for the research. It was expressed in the official writing of the Kırklareli University Scientific Research and Publication Ethics Board dated 24 July 2023 and numbered E-35523585-302.99-91144 that this research didn't contain any ethical violations.

Eğitim Bilişim Ağındaki İspatla İlgili Matematik Ders İçeriklerinin İncelenmesi

Özet:

Bu araştırma Eğitim Bilişim Ağındaki ispatla ilgili matematik ders içeriklerini incelemeyi amaçlamaktadır. Bu nitel araştırmada doküman incelemesi yöntemi kullanılmıştır. Araştırmanın verilerini Eğitim Bilişim Ağındaki ispatla ilgili 35 ders içeriği oluşturmaktadır. Bu içerikler içerik analizine tabi tutulmuştur. Analiz sonuçlarına göre Eğitim Bilişim Ağındaki içeriklerde tüm sınıf düzeylerinde ve tüm öğrenme alanlarında yeterince ispat yapılmadığı saptanmıştır. Yeterli sayıda olmamakla birlikte bu içeriklerdeki ispatları çoğunlukla "Geometri" öğrenme alanına ait ispatlar oluşturmaktadır. "Sayılar ve Cebir" öğrenme alanına ait ispatlar sayıca sınırlı kalmaktadır. "Veri, Sayma ve Olasılık" öğrenme alanına ait hiçbir ispata yer verilmediği görülmektedir. Araştırmanın sonuçları doğrultusunda, tüm sınıf düzeylerinde ve tüm öğrenme alanlarında, teknolojinin potansiyellerinden en üst düzeyde yararlanılarak bilişsel gelişimlere ve sınıf seviyelerine uygun ispatla ilgili daha fazla içerik üretilmesi önerilebilir.

Anahtar kelimeler: COVID-19, çevrimiçi öğrenme, ispat öğretimi, matematik öğrenme ortamı, uzaktan eğitim.

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Research Article

Mathematics Teachers' Experiences Teaching of the Online Distance Education During the COVID-19 Pandemic: Concerns and Adaptations

Mehmet GÜZEL[1], Medine COŞKUN[2], Ayşe ASİL GÜZEL[3], Ali BOZKURT[4]

[1] Ministry of National Education, Şehitkamil Belediyesi Öğretmenler Middle School, Türkiye, mmtgzl1@gmail.com, https://orcid.org/0000-0003-1551-9641

[2] Ministry of National Education, Gazi Abdurrahman Paşa Middle School, Türkiye medinecoskun00@gmail.com, https://orcid.org/0000-0003-2605-5096

[3] Ministry of National Education, Şehitkamil Belediyesi Öğretmenler Middle School, Türkiye ayseasilguzel@gmail.com, https://orcid.org/0000-0002-2698-9852

[4] Gaziantep University, Gaziantep Faculty of Education, Türkiye, alibzkrt@gmail.com, https://orcid.org/0000-0002-0176-4497

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Abstract– The purpose of this study was to investigate how mathematics teachers make sense of their experiences teaching in distance education settings during Covid-19 pandemic in 2020-2022. Interpretative phenomenological analysis was used to design this study which is based on the phenomenological pattern. Eight teachers with at least seven years of professional experience participated in the study. Data were collected through semi-structured interviews and interpreted by interpretative phenomenological analysis. As a result, the following four main themes were identified: struggle adaptation & reflection, lack of interaction, tension between authority and autonomy, and concerns about professional competence. According to the themes identified, teachers underwent a search and struggle process as they attempted to adapt themselves and their students to the new situation from the beginning of the period.

Keywords: COVID-19 pandemic, online-distance mathematics education, emergency remote teaching, mathematics teachers' experiences.

Corresponding author: Ali BOZKURT, alibozkurt@gantep.edu.tr

Introduction

The occupational experiences of teachers have been the subject of numerous studies for several years (Gellert et al., 2013; Hodgen & Askew, 2007). The rapid technological advancements and replacements in teaching materials have opened the doors to varying new experiences for mathematics teachers (Trouche et al., 2012). Although many mathematics teachers lean towards employing technology in education (Önal & Çakır, 2016), only some are capable of using information and communication technologies for mathematics teaching (Yazlık, 2019). However, after the COVID-19 outbreak in December 2019, over 91% of students switched from face-to-face to online distance education (ODE) worldwide (Miks & McIlwaine, 2020). As a result, technology use in education has become a necessity rather than a choice. Both educational institutions and teachers naturally embarked on a quest for how to practice distance education and what to do in this process (Tarkar, 2020). It is necessary to reveal how mathematics teachers interpret these experiences to comprehend their online distance education (ODE) experiences during the pandemic.

The COVID-19 outbreak was declared a 'Pandemic' by the World Health Organization (WHO) on March 11 (WHO, 2020). After the COVID hit, it has been rapidly understood that this is not just a health crisis but has economic, social, and educational aspects (Chan, et al., 2021). People started to meet, shop, and educate online (Borba, 2021) there have been some transformations in education and health, economy, and social fields in the world. In Turkey – where the data was collected- all kind of schools were closed from March 16, 2020, to March 30, 2020, and the Ministry of National Education decided to undertake distance education activities in primary and secondary education via three television channels and Education Information Network (EBA). Some teachers also began to conduct distance education activities voluntarily within this period. However, as of the 2020-2021 school year, a planned and compulsory distance education program has been initiated. Although some education levels (8th and 12th grades) received face-to-face education at certain times during this school year, ODE was implemented for most of the year. In this sense, this study focused on mathematics teachers' online distance education experiences.

In the literature, during the pandemic, education was defined as unplanned, sudden, and temporary practices. Hence, the concepts of distance education, such as; online education, remote teaching, etc. were unable to explain the educations that took place during the pandemic, and the use of the 'Emergency Remote Teaching' (ERT) term was recommended instead (Bozkurt & Sharma, 2020). Unlike distance education, which is scheduled to be conducted online from the beginning and designed for online, ERT refers to the transition to a non-permanent alternate environment where the learner is provided education in an emergency or crisis (Hodges et al., 2020). Thus, it is plausible for the researchers to classify this period as ERT in the first place because the distance education practices in the second semester of the 2019-2020 school year were not within the scope of any plan and program, and teachers lessoned voluntarily. Yet, this study covers approximately one-and-a-half-year period. In the last year of this one-and-a-half-year process, the relevant ministry has tried to provide a robust education ecosystem with distance education. In this context, rather than giving temporary access to education and training support, the courses were planned at the beginning of the semester and conducted within a specific program with EBA. As a result, it is not appropriate to refer to an entire period of time as an unplanned and temporary process. However, the fact that there is no change specific to distance education in the teaching materials and curriculum makes it difficult to say that this process is not entirely ERT. Whether or not it is suitable to refer to a scheduled educational process as online education within this period; or whether it meets other standards are not within the scope of this research. In other words, the conceptual debate about whether or not the education scheduled in this process is ERT is beyond the focus of this study. Therefore, the term ODE will be used as a principal concept in the study.

The meaning of being a mathematics teacher may only be comprehended when the contexts influencing the teaching practices of the mathematics teacher are envisioned (Desforges & Cockburn, 1987). Some of these elements, such as pedagogical content knowledge (Shulman 1986), mathematical knowledge for teaching (Hill et al., 2005), content knowledge (Ball et al., 2008), and technology knowledge (Niess, 2005), are related to teacher’s knowledge and the quality of teaching. Nevertheless, other contexts are linked to social and personal elements such as attitude, emotion, belief, value, and ethics (Bishop et al., 2003; Boylan, 2016; Kuntze 2012; Lee, 2005; Schoenfeld, 2011). Such factors affecting the mathematics teacher's teaching-related variables emphasize occupational knowledge and personal and social variables. Along with these teacher-related variables, the demanding requests of colleagues and school administrations may also be effective in decision-making about mathematics education (Santagata & Yeh, 2016). In addition to the other stakeholders, parents were identified as one of the primary variables in teachers’ decisions in the school (Shapira-Lishchinsky, 2011).

Being a mathematics teacher in ODE is not discussed in this study within the teacher identities but with teacher experiences of struggles that they had to overcome. This study used the interpretative phenomenological analysis (IPA) method, a sort of phenomenological research, focused on teachers' experiences with ODE, the essence of those experiences, and how teachers interpreted the process. Therefore, the data in our research were interpreted by considering these factors impacting the actions of mathematics teachers in the literature. Despite that, the unique context of the pandemic requires new perspectives.

All teachers began working from home since online distance education became available during the pandemic. Working from home may cause alterations in knowledge and skills required by professions and their attitudes and perceptions about their profession (Bloom et al., 2015). In this context, earlier studies may not precisely assess the experiences of mathematics teachers to the pandemic. Several studies in many countries revealed how this pandemic affected mathematics teachers and mathematics education (Baki & Çelik, 2021; Drijvers et al., 2021; Krause et al., 2021). Despite the change in the use of digital and physical materials, the studies carried out in this area show that different countries offer different opportunities and limitations (Drijvers, et al. 2021). This difference leads to different experiences of ODE by mathematics teachers. Therefore, this study aimed to investigate the making sense of mathematics teachers' experiences in teaching in ODE settings during the pandemic some studies have been conducted in Türkiye (e.g., Baki & Çelik, 2021). However, there are some limitations to these studies. For instance, the scope is limited to challenges and remediations, or the participants are from primary schools. On the other hand, we aimed to describe the essence of the mathematics teachers' experiences. Thus, this study provides both deeper and broader findings.

The findings of this study are likely to contribute to the literature in two ways. Firstly, this process could be considered an opportunity to improve preparedness for future comparable situations. Orasanu and Conolly (1993) emphasized that experience plays a significant role in deciding accomplishments. As a personal experience, therefore, this process influence teachers' education practices after outbreak (Engelbrecht, et al., 2023). Such shared human experiences are also envisaged to serve as a mentor for their actions in future crises. During the pre-reading phase of this study, the authors reviewed the previous crises and educational challenges in those periods. These readings helped researchers specify appropriate research questions and issues on which to focus. This curiosity is not exclusive to the authors of this article; many authors also have detailed experiences of humanity in prior crises in their publications (Gosztonyi, 2021). Secondly, knowing how teachers experienced this process throughout the pandemic has the potential to provide insight into how the process may reflect on teaching practices in the future and what the long-term consequences will be. In this context the analysis of the qualitative data will help to find uncover the following question:

– How do mathematics teachers make sense of their experiences of the online distance education during the COVID-19 pandemic?

Method

The study was designed as phenomenological research. Phenomenology defines the real nature of a shared experience (phenomenon) or the shared meaning of experiences (Patton, 2014). The purpose of this study was to investigate how mathematics teachers make sense of their experiences teaching in distance education settings during COVID-19 in the 2019-2020 and 2020-2021 school years. In particular, the IPA approach was adopted, emphasizing the essence of teachers' experiences and how they perceived this process. In IPA, the analytical process is defined as the dual interpretation process. First, the participants make meaning of their world, and then the researchers attempt to decode that meaning to make sense of their meaning-making (Smith & Osborn, 2008). Accordingly, incorporating both interpretations into IPA studies allows for profound and more comprehensive analysis (Pietkiewicz & Smith, 2014). With these opportunities provided by IPA's analytical procedures, it is possible to thoroughly analyze mathematics teachers' experiences in distance education and their interpretations.

Participants

Participants are selected homogeneously in IPA, and the number of participants is usually between one and fifteen (Pietkiewicz & Smith, 2014). In this study, purposive sampling has been carried out by paying attention to similar characteristics of the participants. As this study investigated teachers' experiences in a crisis, the researchers did not predetermine the number of participants. Instead, analysis and data collection took place simultaneously. Data collection was terminated when data satisfaction was achieved. At this stage, the number of participants has reached eight. 8 participants are enough and appropriate to identify similar situations in teachers' experiences accurately and to examine them in depth.

Eight mathematics teachers from different secondary participated in this study. The participants' professional experiences ranged from 6 to 17 years (not a deliberate limit but an emergent situation). Since novice teachers had no prior expertise in face-to-face education, they (novice teachers) were presumed to be inadequate at interpreting their previous mathematics teaching experiences in distance education. Consequently, the study was conducted among experienced teachers with the idea that it would be better to interpret the essence of their experiences in distance education. None of the participants had undergone any training in distance education programs. They experienced this process for the first time. The socioeconomic statuses of schools where the participants worked were also similar. Regarding academic standings, no differentiation was made between schools with low, middle, and high rankings, but priority was given to all public schools. Detailed information about the participants is given in Table 1.

Table 1 Information about the Participants

Participant's:				The school where he/she employed:	
Name	Gender	Experience (year)	Career	Type	Academic achievement
T1	Male	6	Bachelor	Secondary school	Low
T2	Male	17	Master	Science and Art Centre	High
T3	Female	8	Bachelor	Secondary school	Low
T4	Male	11	Bachelor	Secondary school	High
T5	Male	14	Master	Secondary school	Middle
T6	Female	9	Bachelor	Secondary school	Middle
T7	Female	7	Bachelor	Secondary school	Low
T8	Female	9	Bachelor	Secondary school	Low

The findings were not analyzed within the framework of these characteristics of the teachers. however, these characteristics are important for the richness, similarities and differences of the findings. the similarities in the findings were revealed by selecting the schools at the public school and secondary school level and paying attention to the teacher experience between 6-17 years. the selection of both male and female teachers and the diversity in the achievement level of the schools provided the differences and richness in the findings.

Data Collection and Analysis

Data were collected through semi-structured interviews. Since IPA allows more study flexibility, data collection was mostly executed through semi-structured interviews (Pietkiewicz & Smith, 2014; Smith & Osborn, 2008). The question styles proposed in the IPA research were considered while setting the framework for the interview questions (Smith & Osborn, 2008, pp. 61-63). After asking questions about demographic information, participants were briefed about the distance education applications in Türkiye. Afterward, the participants were asked to state how they experienced this process in general and share their experiences. Because in an IPA study, the interview begins with a generic inquiry, the participant is expected to discuss the subject before asking specific questions (Smith & Osborn, 2008, p. 62). While some teachers elaborated on this process in detail, others limited themselves to a more cursory explanation. Therefore, questions were posed to deepen the interview, but no guidance was given to the participants. The questions and scope used in the interview are shown in Table 2.

Table 2 The Questions and Their Scope

Questions	Scope of the question
Can you summarize the whole process? How did you experience the COVID 19 pandemic as a mathematics teacher?	The way the distance education was practiced, and issues encountered in this process, Difficulties experienced in this period, emotional issues, feelings, changing conditions, and things in which teachers gain or lose within the process
Can you narrate your typical online lesson?	Comparison between face-to-face and distance education processes
Can you narrate your typical face-to-face lesson?	Comparison between face-to-face and distance education processes
What is “online education” in your view?	Things changed for a teacher, such as responsibilities, relations with parents, students, and administration
What is it like to be a mathematics teacher in online education?	Pedagogical practices, changing structures, the way how teachers experienced the process, their thoughts, feelings, attitudes, etc.

With the assistance of carefully crafted questions, experiences and interpretations of teachers in the process were acquired comprehensively. Two academics who are experts in mathematics education also provided feedback on the interview questions. Before interviewing the participants, three secondary school mathematics teachers (outside the participants) were pilot interviewed to ensure that the interview questions were clear, comprehensible, and target-oriented. Therefore, there was no need for a second interview since data was saturated successfully in the first interviews with participants. The data analysis for the IPA study was executed according to Smith et al. (2009) by taking into account the hermeneutic circle, which allows the opportunity to reciprocate among the cases. The transcripts of the interviews are generated first, and then the researchers repeat the readings according to this approach (Smith et al., 2009). Each reading generates unique perspectives, and researchers take initial notes on observations and add remarks during this process (Pietkiewicz & Smith, 2014). Three researchers reviewed the transcripts of the interviews and took their initial notes in this study. Later, they discussed these notes and reached a consensus. The essence of the participants' statements and the inferences they conveyed were the focus of these initial notes. "*Feeling helpless and detached from the social world and business life* (T8'; "*Feeling of a virtual wall between herself and her students* (T3)"; and "*Feeling of unable to touch the hearts of students* (T3)" were just a few of these initial notes. The initial notes were quite specific and mainly about the statements made by teachers. Later, the researchers shared the additional transcripts, and the initial noting stage was executed separately. Finally, notes were discussed to reach a consensus by holding a meeting for each transcript.

After the first stage was completed researchers moved to the second stage, which refers to a process of transforming notes into themes (emergent themes). The researchers repeatedly studied their notes rather than the transcript while *transforming them into emergent themes* (Pietkiewicz & Smith, 2014). At this point, the three researchers studied separately on the documents and combined the initial notes from the first stage. Ideas were occasionally exchanged, and, eventually, the structures of themes were developed through a meeting during this process. The common issues stressed by the participants' expressions were considered while choosing the themes. For instance, the notes such as "*Unable to touch lives of children; unable to make eye-to-eye contact; unable to cognize students; and a cold communication process*, etc." indicated emotional connection rather than general communication in the *initial coding* phase. Such statements were clustered under the theme 'unable to establish an emotional connection'. In this way, the themes such as *"The feeling of being lost, feeling inadequate as a teacher, and feeling a loss of authority*, etc." were identified via focusing on the teachers' perceptions of their experiences.

The relations between themes and theme clusters were studied in the final stage (Pietkiewicz & Smith, 2014; Smith et al., 2009; Smith & Osborn, 2008) The themes identified at this stage are categorized based on conceptual similarities, and some of them may be eliminated if they do not entirely fit the emerging structure or provide insufficient evidence. Accordingly, the final list may include several major (super) and minor (sub) themes (Pietkiewicz & Smith, 2014). Thus, weak themes were excluded from the list throughout this procedure, which is the final stage of the analysis, by considering the advice of returning to the scripts and rechecking before concluding the themes (Pietkiewicz & Smith, 2014). Those themes clustered according to their conceptual similarities were categorized in four main themes: Struggle, adaptation & reflection, absence of interaction, authority & autonomy, and concerns about professional competence. The main themes and sub-themes were provided with quotations in the results.

Interpretations of both the participants and the researchers are emphasized during the IPA analysis. The researchers in the IPA process are aware of the significance of interpreting people's mental and emotional states, especially when they may have difficulties expressing themselves (Smith & Osborn, 2008, p. 54). Thus, three researchers working together at each stage carried out the interpretation process in this study. The researchers also worked individually on each participant's analysis before the meetings to evaluate the interpretations. Meetings were recorded so that they could revisit them when needed. Thus, authors tried to prevent interpretations of the data not to being influenced by a single researcher's prejudices.

Findings

According to the analyses results, the following four main themes were identified: Struggle, adaptation & reflection, absence of interaction, authority & autonomy, and concerns about professional competence. The themes and sub-themes are listed in Table 3 to provide a holistic perspective. Each theme is then presented in detail.

Table 3 Emerged Themes and Sub-themes.

No	Theme	Sub-themes
1	Struggle, Adaptation & Reflection	Feeling the absence of materials and methods, used in face-to-face mathematics education Seeking online mathematics education more effective Recognizing the advantages Comparing the new with the old and criticizing the old Re-determining the role of technology Adaptation
2	Lack of Interaction	The lack of emotional attachment The loss of non-verbal communication The inability to communicate effectively Unable to observe students while studying The inability to assess the psycho-social states of the students
3	Authority & Autonomy	Feeling greater responsibilities Feeling lesser responsibilities Excessive interaction with student's parents Tension induced by institutional demands
4	Concerns about Professional Competence	Dissatisfaction with the occupation Feeling inadequacy as a teacher Concern for their students Feeling of being lost

As can be seen in Table 3, there are six sub-themes for Theme 1, five for Theme 2 and four for both Themes 3 and 4. Each theme is explained and elaborated on in the quotes in the following section.

Theme 1. Struggle, Adaptation & Reflection

It appears that, at the beginning of online mathematics education, participants struggled to adjust to new conditions and educational environments, attempting to adapt to this situation and realizing the advantages of online education within the process. Following this stage, it seemed that the participants tended to compare the new and old states and generally recognize the shortcomings of face-to-face education; they attempted to make online education more effective by adapting the new conditions, and accordingly, their perceptions and attitudes towards online education changed. Some participants conceded to online education and defined it as a genuine opportunity to adopt. Others, however, appeared to reject the entire process and perceive it as a temporary state.

Feeling the absence of materials and methods, used in face-to-face mathematics education

Participants were observed to opine that they would not be able to use the materials they were accustomed to in face-to-face education. Hence, they felt deprived. For instance, when T5 adverted his experience in face-to-face education, he wishfully stated, "While I was lecturing geometry, for instance, there were geometric strips and similar materials…, and students liked them, too". It is clear that T5 spoke longingly about the materials he utilized in face-to-face education and that the students were also satisfied with them. The participants also stated that they attempted to address these inadequacies in various ways. Those statements confirmed that the participants yearned for face-to-face education resources and approaches.

Seeking online mathematics education more effective

Participants were deemed to search for a more effective communication channel with students and uncover more productive tools. T6 stated that she made various attempts to invent the best suitable method in the process.

"Usually, I was pointing the camera towards my paper or notebook so that students were able to see what I had prepared beforehand. Because it was evident that understanding something that had already been written was more challenging for them. So, I was pretending as if I was writing on the board newly; I was turning the paper in my hand to make sure they could see it at that moment"

T2 also claimed that he attempted to find new strategies to communicate with his students by his following words. *"We have also made several trial-and-error attempts like writing on board, finding ourselves there, figuring out the best suitable environment and strategy".* When combined with all participant statements on the subject, one could infer that the process directed the teachers to search for solutions. Furthermore, participants who found more effective tools and communication channels by these searches were observed to recognize the advantages of online education.

Recognizing the advantages

After the initial bewilderment, teachers exposed to online education seemed to become aware of *the* valuable aspects of this education. Initially, the participants recognized the benefits of attending classes in the comfort of their own homes, and the participants also realized the more significant values of online education as the process continued. The statements of T1 show that the online education process resulted in a noteworthy change in teachers' perceptions.

"I think everyone calls it before and after the pandemic, and something like that will continue in education. I believe this face-to-face education will take a different format. So, as I said, this online education has to be integrated into somewhere in education. Or, even if the national education system no longer prefers this, the teachers themselves may keep using it." (T1)

These opportunities (online classes, meeting programs, etc.) had already existed before; however, T2, who indicated that he discovered them through online education, showed his excitement in the following way.

"The existence of such a thing is fantastic. This program (online classes) provided us with valuable insight, allowing us access to an area we were previously unaware of. We just realized it, and this practice is becoming increasingly prominent in my style. The thing about which I am furious with myself is why we have waited until the epidemic to act, although we had known about it since Khan Academy?"

T2 intended that his online education experience opened the doors of an era he was unfamiliar with, demonstrating the enormous impact that his experience has had on him. Teachers' required use of online education played a primary role in acquiring these benefits. Teachers who had recognized the advantages and had partially acclimated to the new situation began to criticize the previous education programs by comparing the new with the old.

Therefore, teachers who had to lecture in distance education took the opportunity to assess benefits through experiencing a new teaching approach.

Comparing the new with the old and criticizing the old

It was noteworthy that the participants began to question face-to-face education after getting used to online education. It was noticed that participants reassessed their education profile as they had never considered it before, and they assumed it as imperative. T2 said that "*Actually, there is no point in going and gathering at school, and staying there until 7 PM*". T2 also questioned whether many people must come together and spend a significant portion of the day at school in face-to-face education. Similarly, T1 stated as follows:

"Maybe you will not go to school, but you will not have to pay for transportation. From the Government's perspective, it does not have to construct huge buildings, and no need to hire a cleaning company and have that building cleaned. So you will get rid of all these costs."

Re-determining the role of technology

Soon after the online education started, the participants interiorized to the new circumstances and even adopted their instruction techniques into the new settings. Significant changes were observed in the participants' perspectives on the role of technology during this process. For instance, T2 remarked that "*We initially thought that we should perceive the problem at the micro level such as using paper and pencil and then move on to technology itself. But my faith in the technology increased once I moved straight into it*". It seemed that T2 positioned technology from a supporting element to the center of education.

Adaptation

There seemed to be a struggle and adaptation process based on the participants' experiences. Initially, the participants were observed to face a circumstance where they faltered and did not know what to do. However, their perceptions of online education changed as they worked through the issues over time. For instance, regarding experience and success in online education, T2 expressed his opinion as follows:

"Things are moving slowly. I feel that online education will become more prevalent at the end of this process. In my opinion, it is a bit ambitious, but I believe that online education is the way of the future. Online education is a must. Is it necessary to have so many buildings, schools, classrooms, and time to spend on them? It is a fantastic thing that something like

online education exists. In terms of both time and space, I began to believe that face-to-face education is a waste."

When generally assessed, there were some critical states where the participants changed their minds in the process. Teachers who had the opportunity to evaluate their teaching results somehow, for instance, had a positive impact on their perceptions of online education. T4 noted that he was unable to follow what the introverted students were doing during this period, and he was only able to get some insight into their circumstances after the exam results.

"It was the one that altered my mind about online education for the better. I was concerned about exam results and wondered how my students, namely my introverted students, were doing. Once they scored above a certain threshold, I felt a little better."

T4's perceptions of online education changed positively after the exam results. Teachers who had no chance to perform assessment-evaluation somehow, however, had concerns about the process. T6 emphasized her concern as follows; "*Easier, yes, it is definitely easier to evaluate during online education; however, I do not believe it offers accurate results. I mean, I do not think that the evaluations in online education are 100% reliable*". Therefore, the exam evaluation process emerged as a factor influencing teachers' views on online education.

Another point raised by the participants was that they saw the new conditions afforded by online education as liberating, and they were delighted with the situation. T3 explained, "*You are free of restraints, so you save time and do not have to shuttle between home and school*." T4 said, "Online education is much better for students if they know their responsibilities because attending school is a loss of time for children, " adding that online education was better suited to children who were aware of their responsibilities.

When evaluating the abovementioned examples and other statements in the process, it could broadly be divided into four stages, or they still have gone through some of these stages. These stages are: (1) estrangement/alienation, (2) seeking/struggle, (3) adaptation, and (4) adoption. Initially, the participants felt left alone in an unfamiliar environment with tools they could not utilize. However, they later embarked on a quest to overcome and lectured a preferable education, struggling with the difficulties they encountered in the process. Furthermore, teachers mastered to use of online education tools more effectively when students became accustomed to the teaching environment throughout the process, and they gradually began to recognize the advantages of online education. At this point, by acknowledging that teachers updated their habits and roles, they also attempted to adapt themselves to the process. In the last stage, however, teachers were found to be separated into two perspectives. While more teachers adopted online education with the expectation of it continuing in the future, others believed it should be phased out and thus developed a negative attitude towards it. For instance, T4 said, "I definitely don't think there is a transition or anything like that, zero chance." He thought of the process, as not a shift or development but as a temporary situation.

Theme 2. Lack of Interaction

The lack of interaction emerged as the main theme expressed by almost all participants. The principal features of the lack of interaction were enlisted as follows:

The lack of emotional attachment

The participants stated that when they were unable to touch (metaphorically) or make eye contact with their students, they felt they failed to establish bonds with their students, resulting in estrangement. T7 described her feelings as "*Since I do not see them, I cannot touch them (influence them metaphorically). I cannot make them feel anything*". Other participants expressed similar statements as well. In conclusion, teachers could not establish an emotional attachment with their students in online education. Once teachers failed to achieve this, they either lost their enthusiasm or struggled to motivate their students. Similarly, T6 stated that:

"Of course, being face to face with students and having that emotion is more crucial… There is no such sensation in online education. It is more of an abstract concept. You're alone in a room, and you do not get that particular feeling no matter how students seem to be present there."

Other participants described the same situation similarly, but with different words. Participants complained that using feelings, emotional dialogues, and having eye contact in face-to-face education could have no match in distance education. This sub-theme indicated that, according to the participants, being a mathematics teacher in distance education entailed losing the emotional bond.

The loss of non-verbal communication

Elements such as body language, gestures, facial expressions, intonation, and emphasis in the education process refer to as non-verbal communication. According to the participants' interviews, the inability to employ gestures, facial expressions, and body language in distance education caused teachers to feel incomplete. For instance, T2 stated that:

"Students on Zoom do not see your hands or arms; they only see your face. Since they cannot visualize your arms, legs, or hands, you seem to act as if you do not exist. Communication without hands, arms, or body parts is a significant impediment in education. At the very least, I believe that I failed to lecture without them."

Being unable to use his body limbs as a communication tool caused the participant to act as if he had none. Thus, the teacher was considered to feel dramatically constrained. Although he believed his face was visible through the camera, he seemed unable to use his body limits.

The inability to communicate effectively

Even if the participants did not fully lose their interaction with their students during distance education, they claimed they failed to communicate effectively. As stated by the participants, the limited communication and loss of control over the student due to this confinement, inability to receive feedback, and no assessment on whether or not the student grasped the teaching were signs of failure to communicate effectively. They were all identified as variables that prevent teachers from delivering a successful education in ODE. For instance, T8blamed the limits of the new communication channels as the reason to fail communication with her students.

"…there are resources and receivers, but an issue exists in the communication channel in between. There is no way to send a message and receive feedback. As a result, I think we could not establish constructive communication."

The difficulty in the communication channel also hampered receiving feedback and making healthy communication. Therefore, she referred that, despite the general disadvantages of online education, such as lack of student participation and loss of motivation, she considered that communication was a problem.

Unable to observe students while studying

One of the reasons why teachers dissatisfied with the way of communication they established and deemed it insufficient was the inability to monitor their students while they were studying. Unequivocally, teachers claimed they could neither assess the process (lost the opportunity of monitoring) nor receive feedback and provide input accordingly. T2 expressed this situation as follows.

"I do not have the opportunity to monitor my students when studying. I mean, I do not know whether or not they write it down. You only rely on assumptions. You get feedback from students, but that feedback does not come to you as alive and immediate. They send you a photograph of something or a piece of work generated within a few minutes. So, you cannot see the process; you only see the final picture."

Other participants also indicated that the inability to observe student work during distance education was a limitation and a concern for them.

The inability to assess the psycho-social states of the students

Participants stated that a lack of interaction with students prevented them from observing their improvements in mathematics and their psycho-social situations. T5 expressed this issue as a failure to satisfy in meeting and supporting the humanitarian needs of students.

"Are the students in a good mood that day, are they unhappy, or are they sick? These are all significant aspects of the learning process. So, if the students need assistance, you can observe them at school and touch them emotionally. At least you motivate them."

Based on the expressions on interaction, participants perceived this process as losing the emotional connection with students, missing the opportunity to observe the students while they were working, and failing to provide feedback.

Theme 3. Authority & Autonomy

Another main theme that emerged from the interviews was the authority relationships of the teachers. The participants considered authority relations from two perspectives. They are themselves the source of authority over the autonomy of students, and the school administration is the source of authority over the autonomy of teachers. The sub-themes reflecting the tension between authority and autonomy were as follows:

Feeling greater responsibilities

Different reasons underlined the participants' increased sense of responsibility in online education. T7 felt a sense of new obligations due to the difficulties she experienced in reaching her students, receiving feedback, and her concerns about student progress.

"Our responsibilities have grown significantly, and our students have constantly been sending questions. We answer their questions ... I continuously try to download new resources ... Teaching used to be within the school boundaries, now it turned out to be something unlimited ... I mean, I seriously think that our responsibility has increased. I got tired more and more. Well, it is not important to get tired. I often believe that I am tired of nothing. In that sense, I feel that I am wasting my time."

T7 stated that she was exhausted by wasting her time rather than increasing responsibilities and workload. In addition, expressing that her teaching responsibilities reached beyond the school boundaries and turned into something unlimited was an indication of how exhausted she felt. T6, however, compared her online training to giving seminars and stated that she felt obligated to plan for this reason.

"…As I said, it had to be more prepared and planned since I could not establish such a connection. Or I felt as if I was giving a seminar. Normally, students in courses would interact with each other. They were asking questions, and I was answering them, etc. Now, I am giving more of a seminar, so I need to prepare ahead of time. I believe that my level of responsibility increased."

T6 referred to her work as a seminar rather than a lecture. What lay beneath T6's feeling to plan more could be the decrease in her self-confidence. In the statements in the following part of the interview, it was evident that the teachers had lost their self-confidence.

"Frankly, I did not want to teach the 8th grade this year because it is a burden of conscience. For the children, it is important to take the lyceum exam. And, I think I could not pass on the information this way. In my opinion, I failed to convey the information from here to the children, even to my best student."

Feeling lesser responsibilities

The participants considered that their obligations had increased on several topics. However, they believed that their obligations on other matters decreased. This issue was demonstrated by T3's following words: "*I feel eased like a bird, I have no responsibilities". It* was noteworthy that while the responsibilities of the participants elevated due to their intrinsic motivations, they thought that their responsibilities (obligations) to the authority lessened.

Being uncomfortable with student autonomy: Issues such as students and teachers not being present in the same settings, students accessing and terminating online classes at their own will, and students' having camera and microphone control during online teaching all caused a sense of loss of authority among the teachers; hence, they were observed to be disturbed by such matters in online education. T6 sensed that the students' ability to set communication boundaries or their freedom to shut themselves off from communication compromised the teachers' authority in online education.

"… there is also this issue. You are in complete control of face-to-face education. So, you may go and check if students have books and notebooks or control what they are doing. But this is not the case in online education. A student may say my camera is off, my microphone is off, or my internet is down, and you cannot confirm it at that moment. I mean, online education was too difficult in terms of teachers' control."

In her following statement, T8also stated that the loss of authority over the students caused emotional stress in her:

"They are there. Students are right in front of me and have audio equipment. But they do not respond to me in any way. So, I feel like students periodically test their teacher's patience. For me, this situation became emotionally and psychologically abrasive and draining."

T8believed that she had lost her control over the students and that the students were deliberately provoking her because they were aware of it. Such an aggressive circumstance demonstrated that the teachers lost their authority over the students within the process."

Excessive interaction with student's parents

Although not every participant mentioned it, excessive contact with student's parents was identified as a sub-theme that should be regarded as an issue. Because this issue evolved as a factor arising from distance education, it put pressure on the teachers in the process. According to T2 and T5, parents' involvement in the teaching process and excessive contact with them put teachers under pressure. T5 expressed his feelings as follows:

"Regarding the student's parents, I think we interacted with them too much. I have to send messages to parent groups and share links with them. Because I feel that I cannot reach my students directly. So, parents became highly visible between the student and me. I was not addressing my students but rather their parents. I wanted the parents to convey my messages to the students. That makes me very uncomfortable. I never want to deal with the parent excessively, but I have to. This issue was something that affected me negatively."

According to T5's claims, the teaching process shifted from a confidential dialogue between the student and the teacher to a procedure that included the parents, which he found extremely disturbing.

Tension induced by institutional demands

Another stressful issue raised by the participants was teachers' discomfort with the school administration's increased requests, directives, and their ability to reach them by phone at any hour of the day. While calling the students at any time was beneficial, T2 expressed the followings:

"To me, the idea that we are somehow out of their control causes them (the school administration) to message (frequent texting) us. I am unsure if the administrators (school administration) cannot fulfil their roles, but there is a constant barrage of irrigative messaging. Even a message saying good morning, if nothing else, begin to irritate me now. The school administration and parents' roles have grown, while the student and teacher's roles have reduced."

It was clearly inferred that the participants experienced this process as a dilemma between authority and autonomy within the context of shifting power and control relations.

Theme 4. Concerns about Professional Competence

Participants began to assume that they could not benefit from their previous teaching experiences and acted as novice teachers upon the start of online education. The following sub-themes revealed this main theme:

Dissatisfaction with the occupation

One of the principal affections experienced by the participants in this process was their dissatisfaction with the education they lectured. This feeling, which seemed to be shared by all participants, was a common theme by several factors such as communication issues, difficulty to make an assessment, poor student participation, and the influence of negative consequences such as stress and burnout. All factors contributed to the participants' assessments of their teaching as ineffective. While T7 stated that she had no indulgence with her profession, T4 indicated that online education was not adequately productive and noted*...much as things were tested in online education, this process let the students fall behind. So, what happened? Of course, it was not quite zero over 100; it was closer to 20 or 30*. T8 also expressed her feeling as *...while I was lecturing, I occasionally felt like I was* *teaching on a blank wall*. With the analogy of a blank wall, T8 seemed to believe that the teaching she provided was in vain. While T2 described his teaching style in online education as "*it is getting towards expository teaching approach*", T1 expressed that "*online education is getting more and more expository teaching approach"*, implying that teachers in online education adopted a strategy that required them to be more active. Teachers also indicated that such practices were imperative rather than optional because they would otherwise fail to interact with their students. Teachers lecturing approaches in distance education appeared to lean toward traditional education, but they eventually gave up since such procedures were very time-consuming. T4 remarked that he quit trying after a while and switched to making presentations to keep up with the curriculum.

"As teachers, there is not much we can do. You hit the wall once and hit the wall twice. But you do not want to strike that wall anymore. You say that teaching it this way is the best because you have a schedule to set. I shifted to making presentations. Perhaps it was also easier for us."

It was also seemed that the majority of the participants were dissatisfied occupationally, felt limited, and were under stress; thus, they chose to compensate for online education by loading excessive homework to students.

Feeling inadequacy as a teacher

The participants seemed to develop a sense of inadequacy by their discontent with their occupations. For instance, T2 addressed this issue as "*There is a deficiency somehow, and we* failed *to overcome it*" While T1 stated that "*Of course, you feel an inadequacy, of course, that was also an effect on that issue*", T5 expressed this situation with the following statement:

"…We also have certain shortcomings considering the use of different applications. Such things are all limiting factors. I mean, we tried to adapt to a new process and a new system. There are difficulties that we experienced. We suddenly found ourselves in this process. There are many factors. It seems that we felt inadequate at this point."

T5 felt inadequate in using the newly required communication tools, especially in online education. He further noted that the rapid changing procedure prevented teachers from improving in this sense. The lack of opportunities for teachers to evaluate their teaching approaches possibly caused a detrimental impact and made them feel this way. T5 drew attention to this issue with his following words: "*How productive I was, and how beneficial I was*". Other participants also believed they could no longer express themselves adequately for classroom control, reaching out to students, and receiving feedback. T6 also remarked that "*teaching experience lost its meaning with online education*". Based on similar statements of other participants, the teachers appeared to feel inexperienced in this new setting and believed that their previous experiences could no longer mentor them. It was also evident that such a situation caused teachers to be concerned for their students and put them under pressure.

Concern for their students

There were different reasons behind the participants' concerns for their students. These were students' poor learning, poor adaption to the new educational environment, failure to use new resources, and low participation in online education. Therefore, teachers seemed to be worried about losing some or all of their students. For instance, T7 expressed these concerns as follows:

"The problem in this process was that many students seriously atrophied and evanished. Unfortunately, we caused this. So, I don't think teachers are that powerful in the process. If more powerful people than teachers did things right, would teachers be more involved? I do not know."

T7 used the term 'evanished' for many of her students. Those students T7 mentioned might be considered the successful group because the expressions 'atrophied' and 'evanished' seemed to refer to this context. T7 also blamed policymakers rather than teachers. As a result, it would be plausible to say she had serious concerns for her students. Finally, it was determined among the teachers that a lack of job satisfaction, feelings of inadequacy, and concern for students also established a ground for the sense of being lost.

Feeling of being lost

While the participants described the problems contended, they defined their feelings as being cut off from professional life and becoming senseless to the world, being incomplete, solitary and alone, disturbed by uncertainty, losing control, and not knowing what to do. These sensations seemed to convey the feeling of being lost. T8 said that '*It was a kind of feeling of desperation. We had already cut off from the social world at certain points, and the same happened in professional life*', stating that she felt detached from the world and felt alone. Furthermore, it was noted that the participants considered themselves in a strange environment and did not know what to do, as evidenced by the statements such as '*It was difficult to adapt*' and '*There was a situation where no one knew what to do*'.

Conclusions and Discussion

This study aimed to investigate the making sense of mathematics teachers' experiences in teaching in ODE settings during the pandemic. The participants stated that they found themselves in an educational setting in which they were unfamiliar and didn't know what to do in the early stages of distance education. With the management of initial chaos, the teachers attempted to make the existing tools and communication channels more effective while also searching for new equipment and ways of communication. This process might be characterized as a struggle and search. Participants in this procedure seemed to prefer to employ the tools (graphic tablet, webcam, etc.) that they considered the most efficient among the equipment they practiced during the online education. As NíFhloinn and Fitzmaurice (2022) stated that, usage of such tools was rising, based on their technical advantages. Teachers realized the potential and limitations of these instruments, which they used compulsorily at the beginning of this process, and improved the instruments' utility as they experienced. This process is described as the adaptation procedure through which teachers modify the tools as suitable for them. Finally, teachers adopted new modes of communication and tools by making decisions through their experiences throughout the process. The literature highlighted that teachers made their own decisions based on their experiences (e.g. Bishop, 2008; Huang et al., 2022). Furthermore, some of the participants appeared to take a negative stance towards online education and adopted resistance, developing a perception through rejecting the effectiveness of online education. Therefore, these mathematics teachers described this process as a general struggle, search, adaptation, and adoption/rejection process.

As anticipated, teachers coped with the challenges originating from the change in communication channels and the limited communication throughout ODE. As in other professions, teachers also considered themselves to feel constrained by the new circumstances generated by work from home and the unorthodox communication style (Ipsen et al., 2021). The lack of non-verbal communication and the inability to observe students while studying were the key elements that directed participants to believe their communication with students was ineffective. Non-verbal communication encompasses individuals' conscious or unconscious behaviors in the presence of others; thus, it is a crucial aspect that directly impacts the quality of teaching (Bambaeeroo & Shokrpour, 2017). As a result, teachers believed they lost the principal components determining the teaching quality besides their rudimentary roles. There seemed to be verbal communication between the teacher and the student; however, non-verbal communication was restricted severely during online education. The fact that the participants rated their communication with students as “poor” indicated that mathematics teaching should be approached in a broader framework covering non-verbal and emotional communication beyond employing mathematical/symbolic language. In the literature, mathematical communication is emphasized mostly by its mathematical communication skills (Cai et al., 1996; Chen et al., 2021; National Council of Teachers of Mathematics (NCTM), 2000). Such skills include the individuals’ correct use of mathematical language, expressing their thoughts clearly, and interpreting the opinions of others (NCTM, 2000). However, the findings of this study revealed clues that non-verbal communication was a significant component of mathematical communication for teachers. In parallel with these findings, spontaneous mathematical discourse in mathematics learning and teaching environments should include activities such as employing the body language of teacher and student and pointing out mathematical objects in addition to verbal expressions (Barwell, 2003). In this regard, the inexistence of non-verbal communication means the teachers lose one of their natural components of the mathematical discourse or, as one of the participants stated, ‘a limb he/she uses in teaching mathematics’. The lack of communication additionally caused teachers to weaken and alienate their emotional bonds with their students. Sakiz (2017) stated that one of the most significant components of a learning environment was teachers’ constructive emotional support, which he defined as dignifying, empathizing, valuing, and providing the need for safety. The participants also stated that they could not perceive their students’ requirements and hence failed them to support. The participants also thought that the responsibility and roles of the teachers, for instance, observing students during studying, mentoring, and acting as a facilitator in education, disappeared during online education. According to Lester et al. (1989) these are fundamental aspects of a teacher's profession.

Teachers mediated themselves as authorities in the classroom and believed their role weakened in distance education. However, they assessed that the school administration's power over them diminished and that, as a result, their autonomy elevated. These findings align with the results obtained by Meisner and McKenzie (2022), thereby corroborating and reinforcing the scholarly work on the matter. According to Piaget (2013), autonomy refers to the ability to self-behave without being influenced by external pressure. As a result, the idea that participants believed their authority-dictated obligations diminished while their sense of responsibilities increased (e.g. T8) could be justified by autonomy. While working from home, the participants experienced a sense of being out of control (Ipsen et al., 2021), and they were pleased with such a situation for themselves. However, they were uncomfortable instead when their students acted uncontrolled. In addition, they opined that they lost classroom privacy due to the unnecessary involvement of parents in the teaching process. Teachers recognizing the erosion of school administration's control over them felt a greater sense of professional responsibility. Therefore, distance education entailed redefining the roles in terms of more responsibility versus less control for the teachers and assigning obligations to students and teachers.

Teachers had concerns about their professional skills since they could not use their previous teaching experiences in the new settings. The most obvious explanation for teachers to have such an opinion was that they neither received feedback nor had the opportunity to evaluate students. This result is in accordance with Flack et.al. (2020) findings that teachers feels being like a beginner teacher, even one of our participant used the exact same sentence to express her feelings. Yohannes et al. (2021) stated that one of the obstacles experienced in distance mathematics education was the lack of proper interaction and feedback. They further emphasized that the unidirectional media tool (only the teacher activities were visible) was the root of the problem since teachers were accustomed to evaluating their students solely on a paper-based. However, Assareh and Bidokht (2011) stated that the major constraint in online education was the assessment and evaluation process. Such feelings seemed to shift positively among teachers (T2 and T4) when they had the opportunity to receive feedback or execute objective evaluation.

Suggestions

As a result, we can say, the entire process turned into a practice in which teachers' previous experiences became obsolete, leaving them as felt being inexperienced, isolated, lost, and alone but paradoxically liberalized. The essence of this feelings is the lack of interaction during ODE. It is safe to conclude that being a mathematics teacher during the pandemic had a traumatic aspect. Life generally includes a continuum that ties the past with the future. Trauma disrupts this continuum by severing the link between the past and the future, generating a gap in the lifeline (Garland, 2018). The participants' thinking that their teaching experience became obsolete and their great confusion might have caused them to perceive the process as a traumatic situation. As Engelbrecht et al. (2023) stated, many things have changed with the school closures during the pandemic in terms of education. Our findings indicate that not all of these changes are positive. In this sense, we suggest investigating teachers after the pandemic process to find out post-traumatic effect on teachers. In future studies, differences and similarities in teacher responses according to variables such as gender and professional experience can be investigated.

The results of this study showed that teachers often tried to find solutions on their own during the crisis. This process of struggle led them to become exhausted or, on the contrary, to discover new ways. Those who were able to manage the process realized the benefits of distance learning, while those who weren't developed prejudices. Therefore, in times of crisis, scheduling should be centralized and the process clearly defined. If teachers are both decision-makers and implementers, yet not authorized, crises can cause new crises..

Compliance with Ethical Standards

Disclosure of potential conflicts of interest

The authors declare that this study and no processes involved in conducting the study have the potential for conflicts of interest.

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Author 1: Conceptualization, Formal Analysis, Investigation, Methodology, Resources, Visualization, Writing - original draft review, and editing

Author 2: Conceptualization, Formal Analysis, Investigation, Methodology, Resources, Visualization, Writing - original draft review, and editing

Author 3: Conceptualization, Formal Analysis, Investigation, Methodology, Resources, Visualization, Writing - original draft, review, and editing

Author 4: Conceptualization, Methodology, Writing – review, editing

Research involving Human Participants and/or Animals

The research was investigated by the Ethics Committee of Gaziantep University with the reference number "E-87841438-050.99-143351 [article 17]." dated 28.01.2022

Matematik Öğretmenlerinin COVID-19 Salgını Sırasında Çevrimiçi Uzaktan Eğitimle Öğretme Deneyimleri: Kaygılar ve Uyarlamalar

Özet:

Bu çalışmanın amacı, matematik öğretmenlerinin 2020-2022 yılları arasında Kovid-19 salgını sırasında uzaktan eğitim ortamlarında öğretmenlik deneyimlerini nasıl anlamlandırdıklarını araştırmaktır. Fenomenolojik deseni temel alan bu çalışmanın tasarımında yorumlayıcı fenomenolojik analiz kullanılmıştır. Araştırmaya en az yedi yıllık mesleki tecrübeye sahip sekiz öğretmen katılmıştır. Veriler yarı yapılandırılmış görüşmeler yoluyla toplanmış ve yorumlayıcı fenomenolojik analizle yorumlanmıştır. Sonuç olarak, dört ana tema belirlenmiştir: uyum sağlama ve yansıtma mücadelesi, etkileşim eksikliği, otorite ve özerklik arasındaki gerilim ve mesleki yeterliliğe ilişkin endişeler. Belirlenen temalara göre öğretmenler dönemin başından itibaren kendilerini ve öğrencilerini yeni duruma adapte etmeye çalışırken bir arayış ve mücadele sürecinden geçmişlerdir.

Anahtar kelimeler: COVID-19 salgını, çevrimiçi uzaktan matematik eğitimi, acil durum uzaktan öğretimi, matematik öğretmenlerinin deneyimleri.

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Research Article

Investigation of Emerging Mathematical Leadership in Mathematics Classroom: Application of Interdisciplinary Mathematical Modeling*

Yunus GÜDER[1], Ramazan GÜRBÜZ[2], Mehmet GÜLBURNU[3]

[1] Adıyaman University, Faculty of Education, Türkiye, yunusguder2010@hotmail.com, https://orcid.org/0000-0002-6595-1953

[2] Adıyaman University, Faculty of Education, Türkiye, gurbuz@outlook.com, http://orcid.org/0000-0002-2412-5882

[3] Mersin University, Faculty of Education, Türkiye, mehmetgulburnu@mersin.edu.tr, http://orcid.org/0000-0001-6270-8619

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Abstract – The aim of this study is to determine the types of mathematical leadership that emerge in the process of applying Interdisciplinary Mathematical Modeling activities taken from real life. For this purpose, the researchers, working with a mathematics teacher and a science teacher, developed two interdisciplinary activities (the Stream Problem and the Energy Saving Problem). The activities were implemented in two groups of 3 and 4 students (11-12 years of age) studying in the 7th grade in a provincial center in the Eastern region of Turkey. In the application process, students put forward their own mathematical and scientific ideas by using their knowledge of mathematics and science in an integrated structure, and by supporting these ideas with group discussions, they produced different models (products). In the process of creating a model, it was observed that some students' came forth within the group, with their mathematical leaderships.

Keywords: Interdisciplinary mathematical modeling, mathematical leadership, middle school mathematics classroom.

Corresponding author: Yunus GÜDER, yunusguder2010@hotmail.com

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Introduction

Leadership is one of those concepts that is quite difficult to define. McCleskey (2014) has argued that it may be futile to search for a single definition of leadership because the correct definition of leadership depends on the researcher's interest and the type of problem or situation being investigated. Leadership is one of the most widely used terms in many areas of human activity, such as education, business, politics, religion, sports, military, etc. Although it is difficult, it is quite important that the leadership has a good definition. Stogdill (1950) defined leadership as "the process (action) of an organized group influencing its efforts toward goal setting and goal achievement". Massarik et al. (1961) gave a similar definition to that of Stogdill, defining leadership as the interpersonal influence exerted in a situation and directed to the achievement of a specific goal or objectives through the process of communication. Kotter (1988) introduced a new perspective on leadership, defining leadership as "the process of directing a group (or groups) towards a specific direction, often in non-coercive ways". According to Mullins (2007), leadership is a process of social influence in which the organization seeks the voluntary participation of its subordinates in order to achieve its goals. Silva et al. (2019), discussing the above definitions, stated that leadership needs to be redefined and defined leadership as follows: "Leadership is the process of interactive influence that occurs when, in any given context, some people accept one among them as their leader, in order to achieve common goals". Like Silva et al. (2019), Stogdill (1950) and Kotter (1988), he has considered leadership as a process. According to Silva et al. (2019), the leadership process takes place in a specific context. If the context changes, the leadership process will also be affected by this. Similarly, Kellerman (2014) emphasized the influence of context in the leadership process. A leader can be defined as the person who assigns others to achieve certain goals, who selects, equips, educates and influences one or more followers with different talents and skills, and focuses them on the mission and goals of the organization (Bostancı, 2012; Winston & Patterson, 2006).

The complexity of the globe, which is changing rapidly every day, affects leadership as well. Although it is possible to talk about different types of leadership in the relevant literature (Gedik, 2020), the most emphasized ones are democratic leadership, authoritarian leadership (Arıkan, 2014) and charismatic leadership. In addition, Bolman and Deal (1991) state that leaders use different methods to define and solve problems and these methods are defined as leadership orientations (Turan et al., 2016). According to this perspective, there are four leadership orientations: structural framework (structure-oriented leadership), human resources framework (people oriented leadership), political framework (transformational leadership) and symbolic framework (charismatic leadership). The structural framework (structure-oriented leadership), which is based on logical thinking and a realistic approach to problems, pays attention to details, develops clear goals and reflects the results of the problems encountered to individuals. The human resources framework (people-oriented leadership), on the other hand, draws a framework that is closely interested in the feelings of the people in the group, supports them, encourages individuals to participate in the negotiation environment, and is open to new ideas. When the political framework (transformational leadership) is examined, it can be seen that these people are individuals with high persuasion skills, equipped with the ability to mobilize (control) people, are politically sensitive and talented, and are very adept at dealing with conflicts. Finally, the symbolic framework (charismatic leadership) consists of imaginative and creative individuals who inspire others, have strong communication skills, are open-minded, care about their culture and values (Dereli, 2003).

In this study, we focused on the types of mathematical leadership that emerge by taking into account the orientations of the students in the middle school mathematics class.

Mathematical Leadership and Theoretical Framework

The importance and leadership of mathematics has been as important as life itself for human beings since the earliest periods of human history. During the era of hunter and gatherers, people used mathematics to determine the weapons they used and the size of these weapons, as well as to determine the animals they would hunt. Between 2500 and 5000 B.C., as a result of the floods caused by the Nile river in Egypt, the boundaries of the landowners' were getting more and more blurry. Mathematics was used to re-define these boundaries (Baki, 2014). In the Sumerians, shepherds represented each animal with a clay cone, collected these cones in a clay bag or a clay cube, kept accounts of death, birth, purchase and sale, in short, they used mathematics to keep an eye of the herd that they looked after. The leadership of mathematics has also shown itself in the election of the chieftain of a tribe. In this tribe, the person who owned the most sheep was deemed as the chief of the tribe. If there were two candidates in the election, the sheep of each candidates were taken out of two adjacent pens, and the first one who had no more sheep to show lost the election. The journey of Pythagoras to learn mathematics, who claimed that numbers ruled the universe and was known as the father of numbers, the fact that Khwarizmi, who called the unknown a "thing", used algebraic expressions that could be considered high-level in his time, the discoveries made by Abu

Kamil, who used algebraic methods in solving problems, and many famous mathematicians that we cannot mention, and the use of their inventions in other branches of science, demonstrate the leadership of mathematics (Clark & Thoo, 2014; Fried, 2007; Heiede, 1992; Mann, 2011).

To this day, we can see that mathematics continues to be the leader of all sciences. As a matter of fact, Gauss's "mathematics is the queen of the sciences" statement, supports this claim. With the development of technology, it can be said that companies that develop completely mathematics-based software are the leading companies in the world. In fact, it is known that these companies make serious contributions to the economy of the countries where they are located. Therefore, mathematics is a leading science because it helps us to understand our surroundings, the environment, nature, our globe and the universe and to gain control over them. Being a leader who leaves a mark requires mathematics knowledge, as it is the leading science.

Although the person who is a leader in mathematics (mathematical leader) is generally better at reasoning skills, self-confident and patient, he may become prominent in the classroom microculture with his/her different characteristics. These features include the development of mathematical thinking skills, the ability to develop different strategies in problem solving, and the ability to make joint decisions by caring about the opinions of others. At the same time, the mathematical leader may show the ability to manage and direct the person or people in the learning environment without realizing it. For example, the answer to a problem posed in a learning environment can be shaped according to the answer of the person who is the leader in mathematics for that particular environment. In other words, the mathematical leader's answer can affect the answers of other people in the group. Nevertheless, other people in the group usually wait for the answer of the person who is considered to be the leader in mathematics, before answering the problem. This shows that mathematical leadership is also important in group studies.

When we evaluate the mathematical leadership framework, different approaches come to the fore in the literature. The trait approach emphasizes that some people are natural leaders and that they have physical characteristics and abilities that distinguish these natural leaders from others (Koçel, 2003). For this purpose, psychological tests were used to find out the characteristics of the leader (Yukl, 1998). According to this approach, the characteristics that a leader must have in the context of mathematics are as follows (Daft, 1991): physically; one must be active, intelligent, knowledgeable, and speak fluently; as a personality, one must be creative, outspoken, honest and take responsibility, socially; one must be cooperative and kind. This approach, which examines the leadership process by only considering the leader variable, has not been very successful. In research, it has been determined that sometimes, leaders in mathematics do not have the same characteristics, and it has also been observed that although there are group members who have more than the characteristics of a leader, they do not emerge as mathematical leaders (Koçel, 2003).

In another approach, the behavioral approach, it is emphasized that what makes a leader successful and effective in mathematics is the leader's behaviors during the leadership process, rather than the leader's characteristics. Whether the leader delegates authority, the way he plans and controls, the way he sets goals, etc. are considered as important factors that determine the effectiveness of the leader. Various applied research and theoretical studies have contributed to the development of behavioral leadership theory. For example; Osborn and Hunt (2007) revealed the existence of two main axes in defining leadership behavior; “establishing structure” and “showing understanding”. Rensis Likert's System 4 Model divides leadership approaches into four groups; exploitative, protective (paternalistic, helpful), consultative management style, and participatory management (Bingöl et al., 2013). The common point of these studies is that leaders pay attention to two things when demonstrating leadership behavior; person and behavior. Studies have confirmed the hypothesis that person-oriented leadership is more successful in the long run, however, various criticisms have been made, ranging from that the concepts used are simplified and generalized to the validity of the methodology used (Dereli, 2003).

In the contingency approach, the basic assumption is that different conditions affect mathematical leadership style. There is no one-size-fits-all leadership style. The main idea of this approach is that a task- or relationship-oriented leadership style cannot be valid in all situations and conditions, that in some cases a task-centered leadership style can lead to effectiveness, and in some cases, on the contrary, a relationship-centered leadership style can be efficient and effective.

There is no single definition accepted by everyone regarding the concept of mathematical leadership, and there is no single type of leadership style suitable for every group. Studies on leadership that have been carried out to date and are still being conducted have revealed different mathematical leadership styles that take into account (a) the environmental conditions, (b) the process in which leadership is experienced and (c) the personal characteristics of the leader (Çelik & Sünbül, 2008). In this context, the current study evaluated mathematical leadership based on the tendencies exhibited by students in a given situation, based on the contingency approach.

Problem Status and Purpose

In this study, in the context of mathematical leadership, middle school students were brought together in groups with interdisciplinary mathematical modeling activities that are related to real life, which can contain more than one solution which are functional, contain complexity compared to classical mathematics problems, and provide science and mathematics concepts together in the same activity. Interdisciplinary Mathematical Modeling (IMM) activities are open-ended, interdisciplinary problem-solving activities that challenge students to build models to solve real-life problems and encourage them to test the models they have built. In this study, considering the theoretical structure of IMMs, two IMM activities were developed that include the learning areas of Mathematics and Science disciplines. IMM activities are inherently complex. IMM makes it possible to create different solutions to problems via using information from different disciplines. The developed IMM activities were distributed to two groups of three and four students, and these groups were asked to work collaboratively and put forward a mathematical model. In the process of creating a model related to IMM activities, it was observed that the students had to cooperate, discussed the positive and negative aspects of the model they created in a purposeful way, and some of them took an active role in the decision-making process about how the final version of the model should be, as a group. In summary, in the process of building a model, it was observed that some students' mathematical leaderships became prominent compared to other members of the group. Therefore, the aim of this study is to examine what kind of mathematical leadership emerges in students in the model building process of interdisciplinary mathematical modeling activities. In this context, the problem of the research is as follows: What are the types of mathematical leadership observed in students during the interdisciplinary mathematical modeling process?

Method

In this study, a multi-tiered teaching experiment (Lesh & Kelly, 2000) was used to determine the types of leadership that emerge in the solution process of interdisciplinary mathematical modeling problems. Multi-tiered teaching experiments, by their very nature, provide learning experiences for all participants and create environments that promote maximum learning. In multi-tiered teaching experiments, participants cannot think independently of each other, even if they are at different levels of learning. Mathematical modeling activities are often used in classroom applications of research designed according to multi-tiered teaching experiments (Lesh & Kelly, 2000).

In the first phase of this study, in which the multi-tiered teaching experiment method was used, the researchers conducted semi-structured interviews with mathematics and science teachers within the scope of interdisciplinary learning and mathematical modeling. In the second stage, the researchers, together with mathematics and science teachers, developed two IMM activities that included the achievements of these two disciplines. In the third stage, the applications of the developed IMMs were made in the teachers' own classrooms. In the implementation process, each teacher implemented the relevant part in regard to his/her own discipline. This study focuses on the discipline of mathematics and the types of mathematical leadership that emerge in the application process of the relevant experiments.

Participants and Implementation Process

Text The participants of the study consisted of two teachers (Mathematics, Science) working in the central school of a province in the Eastern Anatolia Region of Turkey and 7th grade students (12-14 years old) selected from the same school. In the selection of teachers, volunteering and professional experience were prioritized. The science teacher has 10 years of professional experience and adopts a constructivist philosophy in teaching. In addition, the mathematics teacher has 8 years of professional experience and has a master's degree in the field. Both teachers include modeling activities while teaching and encourage their students to create models. Therefore, it can be said that teachers have experience in conducting the modeling activity.

The participating students (4 girls, 3 boys) live in an environment with moderate socioeconomic levels. It was also found that their average score of the 6th grade mathematics course was 87/100. It can be said that this situation has a positive effect on the participant group in terms of their readiness. When the students were evaluated individually as a result of the interviews with the class counselor in the context of their mathematics backgrounds, it was revealed that;

The student with the code S1 comes from a middle-level and non-crowded family structure in terms of socioeconomics. He is the only child of the house. It can be said that he usually participates in classroom discussions and has a good communication with his friends. However, although his 6th grade mathematics achievement score was lower than the class average, it was evaluated that he did not refrain from trying different approaches, especially in problem solving, and was able to explain his solutions.

The student with the code S2 comes from a family structure whose socioeconomic status is not good. He is the eldest of three children. It is emphasized that he does not communicate much with anyone in social life and is introverted. He is one of the students with the best 6th grade achievement score. It was observed that he participated in classroom discussions in mathematics and science courses, but did not participate much in other courses.

The student with the code S3 comes from a family structure with a good socioeconomic status. He is the younger of two children. He is very good in social life and has good communication with his peers. His 6th grade achievement score is above the class average. It was observed that he is active in classroom discussions in all courses.

The student with the code S4 comes from a family structure whose socioeconomic status is not good. He is one of the twin children of the house. He is very good in social life and has good communication with his peers. His 6th grade achievement score is below the class average. He is not very active in classroom discussions during lectures. He remains in the background in problem solving and discussions.

The student with the code S5 comes from a middle-level and non-crowded family structure in terms of socioeconomics. He is the elder of the two children. He social life and communication skills with his peers is not very good. However, he quite enjoys reading books. When his knowledge of this particular subject is sought, he can express himself very well. He is one of the students with the best 6th grade achievement score. He loves to put out a product and to do experiments. In lectures, in class discussions, he can explain the solution of problems well. It has been widely seen that he exhibits unusual approaches to solving problems. He is also a student of the Science and Art Education Center.

The student with code S6 comes from an intermediate-level family structure in terms of socioeconomics. He is the middle one of the three children of the house. He is very good in social life and has good communication with his peers. His 6th grade achievement score is above the class average. Although he is not very active in classroom discussions in Mathematics and Science, he is more active in linguistic lessons such as Turkish and Social Studies. His academic achievement score of the mathematics course is lower than other courses. He has difficulty in solving problems and remains in the background in discussions about solutions.

The student with the code S7 comes from a family structure with a good socioeconomic status. He is the youngest of four children. He is very good in social life and has good communication with his peers. His 6th grade achievement score is above the class average. He is going to a music course in order to learn to play an instrument. In the classroom, he is usually active in all classroom discussions. It has been observed that he exhibits different approaches to solving problems, makes justifications by establishing a cause-and-effect relationship while explaining his solutions.

During the application process of the research, the students were divided into two groups of three and four individuals (group A: S2, S5, S1 and group B: S3, S4, S6, S7). The first of the developed activities was applied to groups in 3 lecturing sessions and the other in 4 lecturing sessions. Each lecture session lasted approximately 40-60 minutes. In all lecture sessions, the science teacher answered the students' questions about the discipline of Science, and the mathematics teacher answered their questions about the discipline of Mathematics. In the first lecture, the teachers informed the students about the problem and introduced the main components of the problem to the students. In the second lecture, the students worked in groups on the concepts in the problem and prepared a list of the givens/requests related to these concepts. The teachers observed the students, gave them tips where necessary, but did not directly intervene with their actions. After the students discussed the concepts related to the discipline of Science in the problem with the science teacher, and the concepts related to the discipline of mathematics with the mathematics teacher, the applications of the third and fourth lecturing sessions were started. In the third and fourth lecture sessions, students identified variables to build a mathematical model of the problem, and tested the model. During the model building process, teachers have overseen the groups, gave tips where necessary, and encouraged students to build models.

Data Collection

Teaching experiments are predominantly concerned with how students do something, just as they are interested in what they do. For this reason, the data collected are usually qualitative rather than quantitative. Cobb and Steffe (1983) state that the qualitative data from the teaching experiments are fed by two main sources: the teaching and the interviews or observations made at regular intervals. Therefore, the data collection tools of this study are video recordings containing the explanations of the students during the implementation process of the developed IMM activities (see APPENDIX 1, APPENDIX 2) and the observations made by the researchers. In addition, the researchers kept notes on both intragroup and intergroup discussions. These notes were evaluated together with video transcripts and this was how the data analysis had been performed.

Data Analysis

In the first step of the analysis, the dialogues of the group members were transcribed and converted into a written text. The discourses in the text were examined according to two characteristics by making explicit coding; narratives and the use of words (Sfard, 2008). The narratives contain mathematical propositions that students accept as legitimate in the process of creating models to solve the problem. The mathematical words used by the students to explain their preferences are shown in bold in the explanations. Each member of the research team participated in the labeling (identification) of these two traits, and the acceptance of problematic definitions was discussed and approved.

In the second step, in which axial coding (Strauss & Corbin, 2007) was performed, the common features of the narratives and mathematical words that were ultimately confirmed were determined in the context of mathematical leadership.

In the third step, in which selective coding (Strauss & Corbin, 2007) was performed, it was attempted to infer mathematical leadership when different narratives shared characteristics related to the same topic around a center. In this process, students' defensive, approving or rejecting discourses were considered as a reference in determining mathematical leadership. In addition, cases in which students actively participated in discussions or listened attentively to other students trying to create new meanings were also used to judge that mathematical leadership was occurring.

In the final stage of the analysis, the inferred mathematical leads were compared and correlated with the data obtained from the observation notes kept by the researchers. Thus, a contribution has been made to the consistency of the determined leadership types (Yıldırım & Şimşek, 2011). The results were presented based on the nature of the data and contributed to the transmissibility of the research results to similar situations.

Results

One of the activities included in this study, which focuses on the types of mathematical leadership that emerge during the implementation process of IMM activities, is the stream activity (see APPENDIX 1). In this activity, which was developed for gains such as the ability to create tables and graphs, to analyze and interprete data, and determine possible outcomes, students were expected to create a model indicating the pollution rates of the waters by using data such as invertebrate insect species, fish diversity, and mineral variety in samples collected from streams from different villages. The type of mathematical leadership inferred in group A during the model creation process is reflective leadership. The narrative about the legitimacy of this type of leadership is shown in Table 1.

Table 1 A Section from the Dialogue Held by Group A in the Process of Solving the Stream Problem

Narrative	The type of leadership that is inferred	Scope
S5: Write (S1 writes from A to E). Salinity: 330, 358, 349, 327, 342. Phosphorus: 20, 25, 35, 30, 40. Nitrate: 25, 35, 30, 45, 40. Nitrogen: 7, 14, 12, 10, 8. pH: 6.8, 6.5, 7, 7.2, 6.7 **S2:** (raising his voice) Let's check the **fish species again** (they check as a group for a while). Ok. **S5:** Salinity… **S1:** The one with the most salinity will be contaminated. **S5:** Phosphorus? **D1:** Should be minimal. **S2:** Look, read here (finds something wrong with the model and shows the reading part). **If the pH is greater than 7, it is clean**. **S5:** then the pH value should be high.	Reflective leader	Actively analyzing previous experiences and actions

When the narrative in Table 1 is carefully examined, it is clear that in group A, S5 wanted to study the mineral structures in order to create a model. However, his lack of communication skills with his peers must have hindered his perception as a leader, and S2's suggestion that fish species should be rechecked was accepted by the group. In their field notes, the researchers stated that the students, especially in group A, evaluated their first discourse based on S2's answers and structured their thoughts around his explanations. In this context, S2, although personally introverted, showed leadership properties in terms of mathematical communication skills within the group. S2 repeatedly reviewed and questioned the variables he wanted to be included in the model. Thus, he had the opportunity to test the accuracy of the ideas he focused on. In addition, S2's rechecking of fish species and re-examination of the activity text indicate that he aims to minimize possible errors in the model. This way of thinking can be associated with the concept of reflectivity, which means actively analyzing previous experiences and actions so that the best model emerges. For example, a student can do reflective thinking by reviewing the mistakes he made in a problem and finding solutions to prevent its recurrence. Therefore, the type of mathematical leadership inferred in this group was coded as reflective leader. S2 analyzed all the variables to come up with the model, and in doing so, actively encouraged in-group discussion. The fact that the group members do not object to S2 shows that this understanding or attitude is perceived by the group members as a leader. “... Let's check again", "If Ph is greater than 7, it is clean". These statements shaped the interaction between class members and allowed students to create and present their own mathematics. When the situation of the same activity in group B was examined, the type of negotiant leader was deduced. The narrative about the legitimacy of this type of leadership is shown in Table 2.

Table 2 A Section from the Dialogue Held by Group B in the Process of Solving the Stream Problem

Quotation	The type of leadership that is inferred	Scope
S3: Which one was the most murky? **S6:** E. **S3:** Then E is the dirtiest. **S6:** Because A is the least murky, so A is the cleanest. **S3: What was T**? **S7:** T is here… **S3: How is the salinity?** It has the maximum salinity, from clean to dirty, so it should be D. **S4:** A has the least amount of phosphorus. The cleanest (according to phosphorus) that is. The one with the least amount of nitrate is A. Again, the cleanest. In terms of nitrogen, again, A is the cleanest. **S3:** Yes	The negotiant leader	To ensure that variables are negotiated by bringing them into the discussion environment

When the above narrative was carefully examined, it can be seen that the students in group B evaluated the variables requested by S3 one by one, not the variables they directly determined, during the model creation phase. S3's high communication skills made him perceived as a natural leader within the group. S3 brought the murkiness variable to the discussion environment and asked the group to discuss this variable. After S6's discourse, he confirmed the value of this variable, making the group accept this value. The fact that S6's mathematics grade was lower than the other subjects made S3 skeptical and he brought salinity to the discussion environment and allowed it to be negotiated. S7's answer must not have satisfied S3, and after S4's answer, he similarly approved the evaluation of these variables. The fact that the group did not object to S3 and left the final approval to him showed that they accepted this situation and considered his views (actions or statements) legitimate. Indeed, according to the field notes the researchers kept, S3, in its role as the final validator, encouraged the group to build models. S3 is a student who has good communication with his peers. Within the group, both his negotiating the variables and his perception as an approving authority indicated that he showed deliberative leader characteristics. Questions such as "Which one is the murkiest?", "How is the salinity? are indicative of the characteristics of a negotiant leader.

Another activity implemented in the classroom microculture is the energy saving activity (see APPENDIX 2). In this activity, students were expected to perform arithmetic calculations, perform conversions between units and create a model by combining variables. In the process of model building, students in both groups A and B had discussions to test the accuracy of mathematical operations and reasoning, and exhibited controlling approaches in the context of mathematical leadership. In short, the understanding that enables this type of mathematical leadership, which we call controlling leadership, to be accepted by students is the presence of leaders who closely follow the roles of group members in the problem-solving process, distribute roles and check the accuracy of the solutions. The narrative about the legitimacy of this type of leadership is shown in Table 3. The narrative shows that students in group A tend to check data on solutions of problems by establishing cause and effect relationships.

Table 3 A Section from the Dialogues of Group A in the Process of Solving the Energy Saving Problem

Quotation	The type of leadership that is inferred	Scope
S2: Vacuum cleaner (brand D) 99.88 kilowatts. **S5:** Let's look at the TV. 103… **S2: You add it as 100+3, right?** **S5:** Yes **S2:** Okay, tell me. **S5:** 103 times 365 **S1:** 37,595 **S2:** Are you sure? **Did you divide by 1000?** **S1:** I'm sure. **S5:** 1010 times 364 divided by 10... (They calculate the energy consumption of the brand A iron. They convert 52 weeks into days). **S2: Divided by 1000 (There are laughs)** **S5:** Divide by 1000. **S5:** 367,64.	The controlling leader	Closely monitoring the roles of group members in the problem-solving process and checking the accuracy of the solutions

When the narrative in Table 3 is carefully examined, it can be seen that S2 tells S5 what actions to take by telling the values of each brand in the problem, together with their units. In addition, S2 tested which operations S5 performed mathematically by asking various questions. Then, combining the problem data, he told S1 what actions to take and asked him questions such as "Are you sure? Did you divide by 1000?" and checked the accuracy of the operations made. The fact that the group members do not object to this understanding or attitude shows that S2 is perceived as a leader who monitors the problem solutions of the group members and controls all the details. As a matter of fact, in the field notes kept by the researchers, it was stated that the students in group A validated their discourse through S2's answers and structured their own solutions after passing S2's control. Although S2 did not have good communication with his peers, he showed leading and controlling characteristics in this activity in terms of mathematical communication within the group. The main factor of him being in control is that he tells the group members what they shall do, reviews what they do and tries to prevent mistakes. When the situation of the same problem in group B is examined, the narrative about the controlling leadership type is shown in Table 4.

Table 4 A Section from the Dialogues of Group A in the Process of Solving the Energy Saving Problem

Quotation	The type of leadership that is inferred	Scope
S3: 357 thousand... 357.7. Now let's find refrigerator B. **You tell him (he looks at S7) he can multiply (S4), and I'll write it down.** **S6:** 955 times 365. **S4:** 348 comma 575. Divided by: 1000. Is equal to: ? **S3:** (**He takes the calculator from S4)**. One minute. 348,575 divided by 1000 equals (Judging by the result on the calculator) something like this came up. **Teacher:** Try again? **S3:** 955 times 365. 348,575. Hmm, okay, calm down, why didn't you tell me about this comma. **S7:** 348 thousand 575 divided by 1000 equals: 348 comma 575.	The controlling leader	Closely monitors the role of group members in the problem-solving process and verifies the solutions with a calculator

When Table 4 is carefully examined, it can be seen that the students in group B questioned the mathematical operations and the variables of each brand in the problem one by one in the model creation process. The group members checked the accuracy of the mathematical operations using a calculator by conducting mathematical discussions among themselves. S3 determined the values of each brand in the problem and told the group members what operations they should do on the calculator. Following this, the group members tried to find out the results of the operations with a calculator. S3 has determined who will perform the operations by distributing the tasks in the group. The fact that the group members do not object to this understanding or attitude shows that S3 is perceived as a leader who monitors the problem solutions of the group members and controls all the details. As a matter of fact, in the field notes kept by the researchers, it was reported that the role distribution of S3 was effective in group B and that the model was created according to the calculations of the people responsible for those roles. S3 is a student with strong communication skills. The main factor of him being a controlling leader is that he focuses on the roles of the group members and verifies the results using a calculator and also gives directions such as "You give the numbers (looks at S7) he can multiply (S4) and I can write the results down". He also takes the calculator from S4.

Conclusions, Discussions and Suggestions

In this study, IMM activities taken from real life were put to work in a middle school mathematics classroom setting and we focused on the mathematical leadership tendencies that emerged during the application process. The first activity, in which two different actions were employed, is an IMM activity (Stream problem) developed for the teaching of creating tables and graphs, data analysis and interpretation, and determining possible outcomes, and the other is an IMM activity (Energy Saving problem) that requires mathematical calculations and conversions between units, and aims to produce a model by combining variables. Two groups formed in the classroom microculture were asked to create a mathematical model suitable for the given specific problem and the types of mathematical leadership that emerged in this process were examined. In both activities, certain students within the group directed the interaction and were able to manage the process. It can be said that the mathematical leadership types that emerged in the study coincide with the leadership understanding defined by Silva (2016). In this context, the legitimate actions and discourses of the group members related to model building have created the context of mathematical leadership and have drawn an image that distributes mathematical roles and actively contributes to the formation of the model (Winston & Patterson, 2006).

Regarding the stream problem, in group A, S5's questioning attitude was prominent, while his lack of communication with his peers prevented him from being perceived as a leader by the other members of the group. It was found that the students in group A evaluated their first discourse through the answers of S2, who has an introverted personality trait, and structured their thoughts around his explanations. S2 has taken care to analyze the mathematical ideas that have been put forward by involving other members of the group in the process of creating a model. This action was considered legitimate in the group. In addition, reconsidering the variables given in the problem and questioning the answers of their peers shows that he aimed to minimize possible errors. This indicates solid behaviors that reveal reflective leadership. As a matter of fact, according to the literature, the personality traits such as inspiring others, having strong communication skills, being open-minded, caring about the culture and values, having strong imaginative and creative skills are also expected from leaders who are described as charismatic (Dereli, 2003). In this context, it can be said that reflective leadership is open to mathematical inquiry and legitimizes norms that minimize the possibility of error in classroom microcultures. However, it can be said that the reflective leader is closer to authoritarian temperament in terms of dominating individuals, observing what individuals do, controlling their activities (Turan et al., 2016), closely supervising learners, more speaking than listening and similar behaviors. When the application process of the same activity in group B was examined, it was seen that the response of the group was shaped according to the answers of S3. S3, who has high communication skills, was the one who made the final decision by filtering the answers of his peers through his own mental process. S3 took a skeptical approach to the answers of the group members, had the answers discussed and negotiated within the group. In this context "Which one is the murkiest?" and "How's the salinity? and questions similar to these indicate negotiant leadership. As a matter of fact, it is an attitude expected from leaders who are closely interested in the feelings of the people in the group, support them, encourage individuals to join the group and draw an open framework for new ideas (Dereli, 2003). In addition, it can be said that negotiant leadership includes behaviors belonging to the democratic leadership (Goleman et al., 2002). The democratic style helps to bring to the surface the ideas on how to perform the best mathematical model, or to generate fresh ideas for doing so. However, when these ideas are over-relied upon, it is inevitable to have too many conflicting ideas and it will be impossible to reach a consensus. In addition, a leader who lacks the ability to adapt to a wide variety of ideas will be more prone to adopt the wrong ones. It has been accepted as a principle that the type of leadership that is democratic, participatory and attaches importance to the solidarity of ideas is better than authoritarian leadership. However, it would not be wrong to say that this may vary according to the characteristics of the working environment and the group (Arıkan, 2001).

Regarding the Energy Saving problem, it is seen that in group A, the leader was S2. In the problem-solving process, S2 controlled the actions of the group members by organizing the data in the problem, directing them and telling them what actions they should take. The members of the group observed S2 and did not object to his actions. With statements such as "You add 100 and 3, right?" and "Did you divide it by 1000?", it has been observed that he verifies the data and operations of his peers and adopt a controlling leadership in solving the problem. In the implementation process of the same activity in group B, it was realized that S3 directed the group and distributed tasks in the group. S3 told the group members what operations they should perform on the calculator in the process of solving the problem and checked the results himself. The fact that the other members of the group did not object to S3 shows that they perceive him as a controlling leader. His discourse "You tell him (he looks at S7) he will multiply (S4) I will write the results down" and him taking the calculator from S4 are indicative of controlling leadership. Based on the fact that the leader himself determines which jobs will be done and how these tasks will be carried out, we can say that controlling leadership also has authoritarian characteristics. As a matter of fact, there are characteristics that overlap with controlling leadership in the context of characteristics that are based on clear logical thinking and realistic approach to problems, paying attention to details, developing clear goals, and holding individuals responsible for the consequences of the problems encountered. It can be seen that these people are individuals with high persuasion skills, equipped with the ability to mobilize people, are politically sensitive and talented, and are very adept at dealing with conflicts. "Hmm, okay, calm down, why didn't you tell me about this comma." This discourse shows that S3 is also mathematically effective in this regard.

As a result, in this study, the types of mathematical leadership legitimized by the students in the mathematics class of a secondary school where IMM activities were implemented included reflective, negotiant and controlling normatives. Although some of these normatives surprised the teachers who implemented it, it can be said teachers mostly agree with the general results obtained by the study. In this context, it is inevitable that the effects of these normatives on mathematics learning/teaching will open new horizons for both the teachers and educators working in the field.

Compliance with Ethical Standards

Disclosure of potential conflicts of interest

The authors declare that this study and no processes involved in conducting the study have the potential for conflicts of interest.

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Author 1: Conceptualization, Data curation, Formal Analysis, Methodology, Resources, Writing - original draft, review, and editing

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Author 3: Conceptualization, Methodology, Writing – review, editing

Research involving Human Participants and/or Animals

Ethical standards were followed in the writing of this article.

Matematik Sınıfında Ortaya Çıkan Matematiksel Liderliklerin İncelenmesi: Disiplinler Arası Matematiksel Modelleme Uygulaması

Özet:

Bu çalışmanın amacı, gerçek yaşamdan alınmış Disiplinler Arası Matematiksel Modelleme (DMM) etkinliklerini uygulama sürecinde ortaya çıkan matematiksel liderlik türlerini belirlemektir. Bu amaçla, araştırmacılar bir matematik ve bir fen bilimleri öğretmeni ile birlikte çalışarak disiplinlerarası iki etkinlik (Dere Problemi ve Enerji Tasarruf Problemi) geliştirmiştir. Etkinlikler Türkiye'nin Doğu bölgesinde bir il merkezinde 7. sınıfta öğrenim gören 3 ve 4 kişilik (11-12 yaş) iki gruba uygulanmıştır. Uygulama sürecinde öğrenciler matematik ve fen bilimleri ile ilgili bilgilerini bütünleşik bir yapıda kullanarak kendi matematiksel ve bilimsel fikirlerini ortaya atmış, bu fikirlerini grup içi tartışmalarla destekleyerek birbirinden farklı modeller (ürün) ortaya koymuşlardır. Model oluşturma sürecinde grup içinde bazı öğrencilerin matematiksel liderliklerinin ön plana çıktığı görülmüştür.

Anahtar kelimeler: Disiplinler arası matematiksel modelleme, matematiksel liderlik, ortaokul matematik sınıfı.

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APPENDIX 1

Stream Activity

Since water is indispensable for all living things, its pollution leads to a decrease in biodiversity in nature. Substances mixed into water sources for various reasons cause pollution by changing their chemical, physical and biological properties, such as lakes, rivers, seas, oceans and groundwater. Due to water pollution, some life forms die, while others carry pollution throughout the food chain. In order to prevent this, we must protect natural water resources and prevent unnecessary water consumption.

One of the important water sources of our province is the Kadran Stream. The Kadran Stream starts from the Kadran Mountains and flows into the Göynük Creek and then into the Murat River. The local folk do fishing in this stream and also use it to irrigate their farmland. This stream is inhabited by creatures called invertebrates which do not posses any skeleton in their structures, as well as various species of fish and insects. There are five different villages (A, B, C, D and E) en-route where the Kadran stream flows. The village of A is located near the source of the stream, and the village of E is located near the river where the stream flows into. The villagers use this stream to irrigate their farmlands. The increasing pollution of the stream in recent years also negatively affects the products grown by the villagers.

Teachers in the Environmental Conservation Club of our school organized a competition for 7th grade students to investigate the effect of pollution in Kadran Stream over the crops grown in these villages. In this competition, the students were divided into 5 groups and each group collected samples from the sections of the stream flowing into the villages. Thus, the samples taken will be examined and the pollution rates of the water taken from the villages will be revealed. The factors affecting the pollution rate of the water of the stream can be listed as follows: i) Invertebrates living in the water affect the pollution rate. While some invertebrates are very sensitive to pollution, others can be less sensitive. The sensitivity level of invertebrates is classified as follows: Between 5-10 “**Very Sensitive**”, between 3-4 “**Moderately Sensitive**” and between 1-2 “**Less Sensitive**". The more invertebrates that are sensitive to pollution in a body of water, the cleaner that water is. ii) The diversity of fish species is the second factor in determining the pollution rate of the water. The number of fish living in a body of water is inversely proportional to the pollution rate of that body of water. In other words, the more fish species live in a body of water, the cleaner that body of water is. iii) Other factors affecting the pollution rate of water are factors such as the amount of dissolved oxygen, phosphorus, nitrogen, salinity of the water, weed species living in the water, and the pH level. The pollution rate of water is directly proportional to the amount of phosphorus, nitrogen, salt and harmful weed contained within it, and inversely proportional to its dissolved oxygen content. pH is a unit of measurement that indicates the degree of acidity or alkalinity of a solution. The pH value of water indicates the density of hydrogen ions within it. The pH density of water is measured with numbers ranging from 1 to 14. At pH 7, water is neutral. Waters with a high pH value are generally considered cleaner.

Preparation Questions

1) “What do you understand by the expression ”invertebrates"? Draw the image of an invertebrate creature.

2) How does the degree of sensitivity of invertebrate creatures change?

3) Why did the teachers of the Environmental Conservation Club organize such a competition? Please explain.

4) What are the factors affecting the pollution rate of water?

5) How do factors such as the amount of dissolved oxygen, phosphorus, nitrogen, salinity of water, harmful weed species living in water, affect its pollution rate?

6) What does pH mean? What pH numbers can water have?

THE PROBLEM OF DETERMINING THE POLLUTION RATE IN THE STREAM WATER

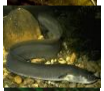
Teachers participating in the Environmental Conservation Club needed a model (system) to evaluate the data collected by students. The samples collected by the students from A, B, C, D and E villages are given in Table-1 and Table-2. Based on these samples, determine the pollution rates of the water collected from each village and develop a model showing the pollution rates of these waters so that teachers can easily evaluate the data of all 5 groups in this model you developed.

Good luck…

Species	Length	Features	Shape	Score	Number (Pcs) A	B	C	D	E
		Very sensitive							
Caddis worm	above 20 mm	They live around the streams that flow rapidly into fresh waters. They have a silky structure that protects their soft tissues.		6	12	7	9	3	10
Dragonfly	18-50 mm	They are short and thick with wing pads and internal gills. All six legs they have are located around their heads.		6	7	6	10	14	9
May bug	10-20 mm	They live only in clean waters with high amounts of oxygen. They breathe using their gills.		7	5	7	2	4	6
Stonefly	above 50 mm	With their three-limb legs and long antennae, they need large amounts of oxygen.		8	3	4	5	2	1
Mite	5 mm	The adult ones swim and crawl freely. They usually live as parasites.		5	5	6	3	7	4
		Moderately Sensitive							
Freshwater shrimp	10-30 mm	It is also known as the brine shrimp.		3	3	5	7	2	4
Freshwater mussels		They are classified within molluscs. They have two shells.		3	4	4	4	3	5
Leech	3-15mm	They are worms that are segmented at one or both ends. In addition to living on plants, they can also roam freely in water.		3	8	7	4	10	12
Flatworm	2-5mm	Even if they lose a body part, they can reproduce it. They roam free.		3	7	8	5	6	4
Snail	10-20 mm	They resemble water snails, but are smaller.		3	5	5	6	3	4
		Less Sensitive							
Water scorpion	30 mm	They have legs that they use to hunt. They are carnivores and feed on small insects. They are usually found in mudflats of streams		2	6	8	10	7	6
Bloodworm		They resemble red thin worms. They have no legs.		2	7	5	5	4	6
Mosquito larvae		They can turn and curl. They have fins to swim in water.		2	8	6	3	5	9

Figure 1 Invertebrate Species Found in the Stream and Their Sensitivity Levels

Table 1 Species and Numbers in Each Region

Fish species	Example	A	B	C	D	E
Swordtail		5	2	2	1	1
Snake		0	0	0	1	1
Mosquito		3	5	3	2	3
Guppy		0	0	1	1	1
Carp		3	4	7	7	9
Types of Harmful Weeds						
Woodruff		2	3	3	3	1
Yellow		1	2	3	3	4
Wormseed		5	2	1	2	3
Devil's weed		2	3	3	1	1
Fireweed		1	1	4	4	2
Chemical Analysis						
Dissolved Oxygen		102	63	75	82	78
Blurriness		12	14	13	11	15
Salinity		330	358	349	327	342
Phosphorus		20	25	35	30	40
Nitrate (NO_3)		25	35	30	45	40
Nitrogen (NH_3)		7	14	12	10	8
pH		6.8	6.5	7	7.2	6.7

APPENDIX 2

Energy Saving Activity

Mr. Serhat and Mrs. Meral, both teachers, went to a large store selling household goods for the house they were going to move to. In this store, where there are four different brands, they will buy a refrigerator, a washing machine, a dishwasher, TV set, a vacuum cleaner and an iron. Since the prices of these four brands are close to one other, Mr. Serhat and Mrs. Meral could not decide which brand to buy. For this reason, they will decide which products they will buy, taking into account the energy, motor power, time to be used and the product features in Table 1 of each brand. Energy is the amount of energy expended per unit of time. The unit of electrical energy is Watt(W). The motor power of the device is also taken into account when calculating the energy. Motor power is the energy consumed by the motor to which the device is connected, per unit time. The total power consumption is the sum of the average power and the engine power. The amount of electrical energy consumed by electrical appliances also depends on the time they are used. For example, a night light powered by a 200 Watt bulb consumes 200 Joules of energy in 1 second, while the same lamp consumes 400 Joules of energy in 2 seconds. As the operation time of electric appliances increases, the amount of electrical energy they consume also increases. When calculating the energy consumption of a device in duration/hour, the unit of power is taken as kilowatts. 1 kilowatt (kW) is equal to 1000 watts. Some features about the products are given below:

 There are other features that should be considered in addition to its energy consumption when buying a refrigerator. Food can spill in refrigerators with shelves in the form of wires as they will have gaps between them. In refrigerators with glass shelves, this is not the case. Recently, refrigerators with glass shelves have become more popular. The internal capacity of refrigerators may vary depending on the number of people in the household. In addition, refrigerators with longer storage times in case of power failure are preferred .

 When choosing washing machines, the number of people in the family is also taken into account. Crowded families prefer machines with more washing capacity. The higher the number of programs and the speed of tumble dry spin of a washing machine, the higher they are preferred.

 When it comes to vacuum cleaners, their dust storage volumes, filter types and noise levels are taken into consideration. The larger the family, the bigger the dust bag usually is. Another reason for preference is the low noise levels in a vacuum cleaner. In addition, vacuum cleaners water filters have also been popular lately.

For a TV set purchase, features such as resolution, screen size, image refresh rate are taken into account. Since the images of TV sets with a higher resolutions will be clearer, they

are preferred. On LCD televisions, the screen size is specified in inches. 1 inch is approximately 2.5 cm. In addition, televisions with higher refresh rates are more popular.

Characteristics such as steam pressure, type of base and water intake capacities are taken into account when purchasing irons. Irons with ceramic bases with high steam pressure are preferred.

In the purchase of dishwashers, machines with a large number of programs and low water consumption are preferred. Recently, inox dishwashers which does not keep fingerprint stains are preferred.

Preparation Questions

1. What is energy and motor power? Please explain.
2. What are the features that should be considered in addition to energy saving in the purchase of refrigerators and washing machines? Please explain briefly.
3. What are the features that should be considered in addition to energy saving when purchasing dishwashers and vacuum cleaners? Please explain briefly.
4. What are the features that should be considered in addition to energy saving in the purchase of irons and TV sets? Please explain briefly.
5. What is the relationship between watts (W) and kilowatts (kW)?
6. Do the following operations.

a) 4 W = ………. kW b) 0,25 kW = ………W

Question: Mr. Serhat and Mrs. Meral will choose from the products of the following 4 different brands, taking into account their energy saving properties. In product selection, develop such a model by taking into account energy saving and the features given in the table so that this couple will be convinced and buy the brands you recommend. *Note: The products may be from different brands.*

BRAND A

PRODUCTS	ENERGY (WATTS)	MOTOR POWER (WATTS)	NUMBER OF DAYS/WEEKS	FREQUENCY OF USE
Refrigerator	970 W	10W	365	Non-stop
Washing machine	2000 W	25W	52 weeks	4 Times a week
Vacuum cleaner	990 W	15W	104 days	30 minutes
TV set	100 W	3W	365 days	5 hours
Iron	1000 W	10W	52 weeks	5 Hours a week
Dishwasher	1200 W	15W	52 weeks	5 Times a week

BRAND B

PRODUCTS	ENERGY (WATTS)	MOTOR POWER (WATTS)	NUMBER OF DAYS/WEEKS	FREQUENCY OF USE
Refrigerator	950 W	5 W	365	Non-stop
Washing machine	2010 W	20 W	52 weeks	3 Times a week
Vacuum cleaner	975 W	10 W	100 days	30 minutes
TV set	98 W	2 W	365 days	7 hours
Iron	1075 W	10 W	52 weeks	4 Hours a week
Dishwasher	1215 W	15 W	52 weeks	3 Times a week

BRAND C

PRODUCTS	ENERGY (WATTS)	MOTOR POWER (WATTS)	NUMBER OF DAYS/WEEKS	FREQUENCY OF USE
Refrigerator	940 W	10 W	365	Non-stop
Washing machine	1950 W	25 W	52 weeks	5 Times a week
Vacuum cleaner	950 W	10 W	108 days	24 minutes
TV set	105 W	5 W	365 days	3 hours
Iron	1050 W	10 W	52 weeks	6 Hours a week
Dishwasher	1125 W	15 W	52 weeks	6 Times a week

BRAND D

PRODUCTS	ENERGY (WATTS)	MOTOR POWER (WATTS)	NUMBER OF DAYS/WEEKS	FREQUENCY OF USE
Refrigerator	1000 W	9 W	365	Non-stop
Washing machine	2100 W	20 W	49 weeks	3 Times a week
Vacuum cleaner	900 W	8 W	110 days	20 minutes
TV set	110 W	5 W	300 days	4 hours
Iron	1100 W	10 W	52 weeks	3 Hours a week
Dishwasher	1150 W	15W	52 weeks	4 Times a week

Figure 1 Brands of Products

Table 1 Specifications of Products

Type	BRAND A	BRAND B	BRAND C	BRAND D
Refrigerator				
Internal Capacity	350 L	400 L	450 L	500 L
Storage Time in Case of Power Failure	30 hours	45 hours	40 hours	45 hours
Shelf type	Wire	Glass	Wire	Wire
Washing machine				
Washing Capacity	3kg	7 kg	6 kg	7 kg
Number of Programs	3	5	9	7
Tumble dry speed	800	900	1100	1000
Vacuum cleaner				
Storage Volume	2 L	2,5 L	3 L	3,5 L
Type of Filter	Dust bag	Water filter	Dust bag	Water filter
Noise Level	76 dB	78 dB	80 dB	77dB
Iron				
Type of Base	Ceramic	Teflon	Ceramic	Teflon
Steam Pressure	5 bars	4,5 bars	4 bars	5,5 bars
Water Capacity	1200 ml	1300 ml	1000 ml	1100 ml
TV set				
Resolution	1920x1080	1900x1000	1850x980	1800x960
Screen Size	47 inches	46 inches	45 inches	44 inches
Refresh Rate (HERTZ)	200 Hz	175 Hz	200 Hz	180 Hz
Dishwasher				
Number of Programs	2	3	6	5
Color	Glossy Black	Glossy Burgundy	Inox (no fingerprint stains)	Inox (no fingerprint stains)
Water consumption	10 L	12	13 L	14 L

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Research Article

The Relationship Between Gifted Students' Self-Efficacy Perceptions of Computational Thinking Skills and Information Technologies Self-Efficacy Perceptions

Tarık OLPAK[1], Ayşen KARAMETE[2]

[1] Republic of Türkiye Ministry of National Education, Burhaniye Science and Art Center, Türkiye, tarolikpak@gmail.com, http://orcid.org/0000-0001-9712-2407

[2] Balikesir University, Necatibey Faculty of Education, Türkiye, karamete@balikesir.edu.tr, http://orcid.org/0000-0001-8442-2080

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Abstract – Today, due to the developing technologies and compulsory reasons such as pandemics, some educational activities are performed through distance education. For these activities, which are mostly carried out online through computers, tablets, and mobile phones, to be effective, they must address the needs and changing characteristics of the students. In this context, the aim of the research was to examine whether there is a relationship between the self-efficacy perceptions of gifted students regarding their computational thinking skills and information technology. The sample consisted of 130 secondary school students studying via distance education in Science and Art Centers in Balıkesir in the 2020-2021 academic year. As a result of the analyses, it was observed that the gifted students' computational thinking and information technology self-efficacy perceptions were above the average and there was a high positive correlation between them.

Keywords: Special talented students, computational thinking, information technology self-efficacy.

Corresponding author: Tarık OLPAK, tarolikpak@gmail.com

Introduction and Theoretical Framework

The traditional learning-teaching methods have served society well for a very long time. The area of education has changed as a result of the evolving and expanding technologies, and student-centered methodologies are now commonplace. In the modern era, information sharing and access have both improved, and educational activities have been moved into technologically advanced settings. These modifications have eliminated the restrictions of time and place on education and made it widely available (Akgün, 2013). It is anticipated that education that is more widely available will produce more effective outcomes. Technological advancements will improve educational environments and should be designed based on the various needs of teachers and students.

The changing qualities of pupils should be considered to deliver the necessary learning in educational activities. In addition to their knowledge and experience, students' abilities and intelligence areas can vary. As one of these several groupings, gifted students are defined as individuals who are significantly superior to their peers in academic ability, who can learn to think creatively, and who are leaders, have high abilities in leadership and other areas, or have intelligence above normal developments (Worrell et al., 2019). “Gifted/talented students” is a term generally used to describe students who show higher potential than their peers in a particular field. These students may have in-depth knowledge and understanding, generally high academic achievement, and ability to solve complex problems (Gelgoot et al., 2020). Gifted students have certain needs different from their counterparts. To discover and grow their skills, they need help (Bilgiç et al., 2013). In light of their unique demands and abilities relative to their peers, gifted students require more robust educational activities outside of their formal education. (Bakioğlu & Levent, 2013). Additionally, these students should receive support based on their areas of intelligence.

Gardner (1993) described intelligence as having aptitude in one or more areas and coming up with original, workable answers to problems that arise in daily life. Giftedness refers to a person's ability to perform at a higher level than their counterparts in terms of intelligence potential. Instead of the terms “gifted” and “gifted talent”, which are found in the literature, “unique talent” has become more popular and is now used instead. It is seen that the concept of gifted is used instead of the concept of gifted in the “Special Talented Individuals Strategy and Implementation Plan 2013-2017” in the study of the Ministry of National Education (MoNE, 2020). Uncertainty will be prevented in this manner (Özsoy, 2015). The idea of extraordinary talent was favored in this study.

Gifted students receive education at the Science and Art Center on some days of the week after the formal education they continue with their peers. The Science and Art Centers provide five different programs for education. These programs are adaptation program, support program, Individual Talent Recognition program (ITR), Special Talent Development (STD) program, and project production program (MoNE, 2019). The ITR program aims to help students find their abilities through various activities (Özsoy, 2015). Two of these objectives are to develop computational thinking abilities and to raise self-efficacy perceptions of information technologies.

One of the important factors affecting the educational activities of individuals is computational thinking skills. One of the 21st-century talents is computational thinking, which is a type of thought process along with creative, critical, cooperative, problem-solving, and communication skill development (Wing, 2006). According to the International Society for Technology in Education (ISTE), computational thinking, a technical approach to problem-solving, is a skill that everyone should have, not just programmers who think with computer logic (ISTE, 2015). The goal of learning this skill is to increase problem-solving abilities by applying the logic of algorithms to every part of people's lives, not to be able to write programs (Alsancak Sırakaya, 2019). Cross et al. (2016) talked about the strong connection between mathematical thinking, scientific thinking and computational thinking, and stated that the gifted education experience, especially in the field of mathematics and science, offers students the opportunity to develop strong problem-solving skills and improve their cognitive abilities to better understand computational concepts.

Computational thinking skill, which can be acquired at any age from pre-school, facilitates understanding the problem and solving it by breaking it into small parts. Having this skill provides interdisciplinary knowledge transfer, producing creative solutions, lifelong learning, transforming what has been learned, and critical thinking (Gülbahar et al., 2019). Computational thinking, which is considered as the process of logical sequencing, analyzing data, and producing solutions using algorithms, is referred to as problem-solving skills in all fields, especially in science, mathematics, and social sciences. It also promotes interdisciplinary knowledge transfer and strengthens students' critical thinking abilities (Buitrago-Flórez, 2021). When used in both classroom and non-school settings, this skill gives students an advantage and can be helpful for resolving issues that arise in a variety of areas of our life.

It can be stated that self-efficacy belief, which is contributed by the past experiences and the problems encountered, is an important variable for the learning-teaching process, since it affects the individual's behaviors. The idea that a person can carry out a task successfully is another definition of self-efficacy. Self-efficacy belief, which was first expressed by Bandura (1977), was defined as an individual's performance in overcoming difficulties and has gained importance with student-centered teaching approaches (Tekerek et al., 2012).

Information technologies are becoming more and more significant, and for many people in the educational stage of life, using technology properly and efficiently has become mandatory. As a result, every year, instruction in information technology is introduced to pupils in the foundational phases of their education. The goal of providing this early education is to improve people's perceptions of their own information technology self-efficacy (Göçer & Türkoğlu, 2020).

When the studies are examined, it is stated that people with strong information technology self-efficacy beliefs are more willing to use computers and participate in computer-based activities. People who have a strong IT self-efficacy belief tend to use technology more easily and effectively. These individuals are more willing to participate in various activities using computers and are more open to acquiring new technology-related skills (Hatlevik et al., 2018). In addition, it was stated that thanks to these strong skills, they found easy, effective, and creative solutions to the problems they encountered. In other words, those who have strong self-efficacy beliefs in information technology tend to make better decisions and have better usage skills (Seferoğlu & Koçak, 2003). In addition, it can be claimed that those who have a high level of self-efficacy in a particular field are more likely to engage in activities related to that area and have better problem-solving skills. Therefore, it is possible to describe self-efficacy perception as a significant educational variable (Çubukçu & Girmen, 2007).

On the other hand, people with a weak sense of self-efficacy do not prefer difficult tasks and give up quickly in the face of the problems they encounter; it is seen that their anxiety is high and their performance is low. Because of this, it might be said that their success is lower than anticipated. In addition, individuals' misevaluation and low perception of self-efficacy prevent them from demonstrating their abilities (Erden-Kurtoğlu & Seferoğlu, 2020).

Purpose of the Research

The purpose of the study is to ascertain how gifted students perceive their own levels of self-efficacy and information technology self-efficacy in connection with computational thinking skills, and to discover whether there is any relationship between the two and, if so, to what extent. In addition, it is aimed to examine whether self-efficacy perceptions for computational thinking skills and information technology self-efficacy perceptions differ according to various variables (gender, age, class level, parental education level, etc.).

The research looks for solutions to the following sub-problems to accomplish these purposes:

1. What is the level of self-efficacy perceptions of gifted students regarding computational thinking skills?

2. Do gifted students' self-efficacy perceptions towards computational thinking skills differ according to various variables (gender, age, education level, duration of internet use, duration of computer use, educational status of parents)?

3. What is the level of information technology self-efficacy perceptions of gifted students?

4. Do gifted students' information technology self-efficacy perceptions differ according to various variables (gender, age, education level, duration of internet use, duration of computer use, educational status of parents)?

5. Is there a significant relationship between gifted students' self-efficacy perceptions for computational thinking skills and information technology self-efficacy perceptions?

Significance of the Research

When the studies in the literature on acquiring and increasing computational thinking skills are examined, many approaches have been encountered. While some researchers emphasize the importance of enriched activities to gain this skill, some researchers emphasize the importance of activity practices, and some emphasize the importance of group work (Yeni, 2017). When the research in the literature is assessed, it is clear that their main objective is to define the concept and scope of computational thinking abilities. In addition, studies examining the relationship between the individual's perception of information technology self-efficacy and computational thinking skills have not been found. It is also thought that systematic review studies involving gifted students, in which research is evaluated under different titles, current data are processed, and different variables will be included, will contribute to the literature.

Studies in the field of information technology self-efficacy belief generally make comparisons with the demographic information and competencies of the sample. There is no study investigating how computational thinking abilities and information technology self-efficacy beliefs relate to gifted secondary school students. It is thought that determining this relationship will contribute positively to increasing students' self-perceptions and developing their problem-solving skills. In addition, it can be a guide for teachers' approach to students. It is anticipated that the study would help fill the gap on this topic in the literature. On the other hand, the research was limited to gifted students studying in Balıkesir.

Method

This research is a descriptive study in the relational screening model to examine whether there is a relationship between gifted students' self-efficacy perceptions for computational thinking skills and their information technology self-efficacy perceptions. The relational survey model is a type of survey research that aims to determine the relationship between variables, their severity, and direction (Bertiz & Kocaman Karoğlu, 2018; Büyüköztürk et al., 2015).

Sample

In the 2020-2021 academic year, a total of 130 students enrolled in the Individual Talent Recognition (ITR) and Special Talent Development (STD) program, including secondary school students studying via distance education in Science and Art Centers (BİLSEM) in Balıkesir province, constitute the sample of the study. Appropriate sampling method was preferred among the non-random models due to the pandemic in the selection of the sample. Demographic characteristics of the sample are shown in Table 1.

Table 1 Demographics of the Working Group

	Girl			Boy			
Institution	ITR1	ITR2	STD	ITR1	ITR2	STD	Total
Bandırma Science and Art Center	5	3	0	3	2	0	13
Burhaniye Science and Art Center	39	23	4	15	15	8	104
Balıkesir Şehit Prof. Dr. İlhan Varank Science and Art Center	2	1	1	4	3	2	13
Total	46	27	5	22	20	10	130

Data Collection Tools

In order to collect data in the study, the personal information form prepared by the researchers and the scales described below were used. In the personal information form, consisting of 22 items, there are questions about the student's age, gender, family, having computer and internet, and duration of use.

The Self-Efficacy Perception for Computational Thinking Skills [CTSSP] scale developed by Gülbahar, Kert, and Kalelioğlu (2018) consists of 36 items under 5 factors. The factors are algorithm design competence (nine items), problem-solving competence (ten items), data processing competence (seven items), basic programming competence (five items), and self-confidence competence (five items). On a 3-point Likert scale, “No” corresponds to 1 point, “Partly” corresponds to 2 points, and “Yes” corresponds to 3 points. A minimum of 36 points and a maximum of 108 points can be obtained from the scale. The internal consistency (Cronbach's Alpha) value of the scale varies between 0.762 and 0.930 for the sub-factors. When interpreting the scale, high total scores from the sub-factors and the entire scale will provide information that the participants' level of “Self-Efficacy Perception towards Computational Thinking Skills” is high.

Information Technologies Self-Efficacy Perception Scale [ICTSEP], developed by Göçer and Türkoğlu (2018), has 30 items and a single-factor structure. To test the reliability of the scale, Cronbach's Alpha internal consistency coefficient was calculated and Cronbach's Alpha internal consistency coefficient was found to be .90. On a 5-point Likert scale, “Doesn't suit me at all” corresponds 1, “Doesn't suit me” corresponds 2, “I'm undecided” corresponds 3, “Suits me” corresponds 4, and “Completely suits me” corresponds 5 points. A minimum of 30 points and a maximum of 150 points can be obtained from the scale. In the interpretation of the scale, the total score between 30-54 is determined as “very low level”, between 54-78 as “low level”, between 78-102 as “medium level”, between 102-126 as “high level”, and between 126-150 as “very high level”.

Data Analysis Methods

The collected data were analyzed using SPSS version 26 to determine the relationship between gifted students' self-efficacy perceptions regarding computational thinking skills and information technologies self-efficacy perceptions. With the data obtained, descriptive and descriptive statistics such as frequency, arithmetic mean, percentage, and standard deviation were carried out based on the 95% confidence interval and .05 significance level. To compare the obtained data according to two independent variables, the independent samples t-test from parametric tests was used. In addition, Pearson Correlation analysis was conducted to determine the relationship and level between the two variables. To compare more than two variables, Analysis of Variance (ANOVA) and LSD (Least Significant Difference) tests were used for independent samples.

Findings

Findings of the first sub-problem

The self-efficacy perception and factors total scores for the computational thinking skill obtained in the research and the total score of the information technology self-efficacy perception were subjected to explanatory factor analysis. In addition, the lowest score, highest score, mean, and standard deviation values are calculated and given in Table 2.

Table 2 Number of Participants, Average, Minimum, Maximum, Standard Deviation Values of CTSSP and Factor Scores

Variables	N	$\bar{X}$	Min.	Max.	SS.
Self-efficacy perception scale for computational Thinking skill (Total)	130	90.28	53.00	108.00	13.34
Algorithm design competence	130	21.00	9.00	27.00	5.60
Problem solving competence	130	26.57	18.00	30.00	3.07
Data processing competence	130	17.94	7.00	21.00	3.16
Basic programming proficiency	130	11.58	5.00	15.00	2.84
Self confidence competence	130	13.16	8.00	15.00	1.87

p< .05

When Table 2 is examined, it can be stated that the SCBA levels of the gifted students are ($\bar{X}$ =90.28) and the result is above the average as seen in Figure 1.

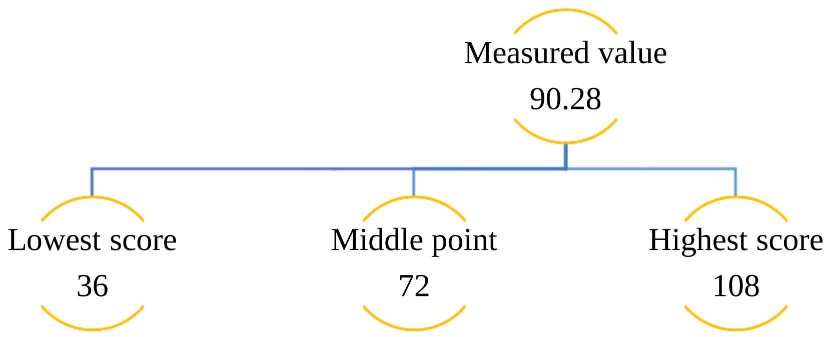

Figure 1 Displaying Participants CTSSP Levels

The Pearson correlation coefficients of the average scores of the CTSSP factors of proficiency in designing algorithms, proficiency in problem solving, proficiency in data processing, basic programming proficiency and self-confidence were calculated. Analysis results are presented in Table 3.

Table 3 CTSSP Factors Total Scores Pearson Correlation Coefficients

Variable	Algorithm design competence	Problem solving competence	Data processing competence	Basic programming proficiency	Self confidence competence
Algorithm design competence	1.00	.339	.538	.629	.533
Problem solving competence	.339	1.00	.602	.437	.577
Data processing competence	.538	.602	1.00	.686	.672
Basic programming proficiency	.629	.437	.686	1.00	.683
Self confidence competence	.533	.577	.672	.683	1.00

p< .05

When Table 3 is examined, between CTSSP factors, there is a weak level correlation on the positive side between Algorithm Design Proficiency and Problem-Solving Proficiency (r=.339; p< .05), and a moderate level on the positive side between Data Processing Proficiency (r=.538; p< .05), a moderate positive correlation between Basic Programming Competence (r=.629; p< .05) and a moderate positive correlation between Self-Confidence Competence (r=.533; p< .05). As for the relationship with Problem-Solving Competence, there was a positively moderate relationship between Problem-Solving Competence and Data Processing Competence (r=.602; p< .05), positively moderate relationship between Basic Programming Competence (r=.437; p< .05) and moderate relationship between Self-Confidence Competence (r=.577; p< .05). It was also found that there was a moderate positive correlation between Data Processing Competence and Basic Programming Competence (r=.686; p< .05), and a moderate positive correlation between Self-Confidence Competence (r=.672; p< .05). Finally, it was found that there was a moderate positive correlation between Basic Programming Competence and Self-Confidence efficacy (r=.683; p< .05).

Findings of the second sub-problem

Table 4 shows the numbers, mean, standard deviation, and t-test values of the scores that gifted students obtained from the CTSSP scale based on their school type, gender, having a room, and having a computer.

Table 4 Number of Participants, Mean, Standard Deviation and t-Test Values of Their Scores from the CTSSP scale

Variables		N	X̄	SS.	*t*
School type	State school	105	89.78	13.74	-.881
	Private school	25	92.40	11.55	
Gender	Female	78	91.25	13.23	1.017
	Male	52	88.82	13.51	
Do you have room	Yes	107	92.13	12.90	3.552
	No	23	81.69	12.17	
Do you have computer	Yes	100	92.37	12.66	3.382
	No	30	83.33	13.41	

p< .05

When Table 4 is examined, the self-efficacy perceptions of gifted students towards computational thinking skills are examined in terms of school type (t= -.881, p< .05), and public school was found to be (X̄=89.78, SD=13.74) and private school as (X̄=92.40, SD=11.55). Although it was higher in the direction of private schools, no significant difference was found. In terms of gender (t= 1.017, p< .05), there was no significant difference between female (X̄=91.25, SD=13.23) and male (X̄=88.82, SD=13.51) students, although CTSSP was higher in terms of female students. In terms of whether the students have their own room (t= 3.552, p< .05), there was a difference between the groups of having a room of their own (X̄=92.13, SS=12.90) and not having a room of their own (X̄=81.69, SD=12.17). It was found that CTSSP was higher in the direction of those who had their own room and there was a significant difference. In terms of whether students have a computer (t= 3.382, p< .05), a high and significant difference was observed between those who have a computer (X̄=92.37, SS=12.66) and those who do not have a computer (X̄=83.33, SS=13.41).

A one-way ANOVA was conducted to determine whether there was a statistically significant difference between the total scores of gifted students from the CTSSP scale and various variables. One-way ANOVA results are given in Table 5. One-way ANOVA test was preferred due to the distribution of the data, the number of groups and because it is an effective analysis method.

Table 5 ANOVA Results of Students' Scores from the CTSSP Scale by Various Variables

Variables	Source of variance	Sum of squares	sd	Mean Squares	F	p
Age	Between groups	322.987	4	80.747	.446	.775
	In-group	22653.482	125	181.228		
	Total	22976.469	129			
Grade	Between groups	199.177	3	66.392	.367	.777
	In-group	22777.292	126	180.772		
	Total	22976.469	129			
Mother's education status	Between groups	1459.995	5	291.999	1.683	.144
	In-group	21516.474	124	173.520		
	Total	22976.469	129			
Father's education status	Between groups	1254.510	6	209.085	1.184	.319
	In-group	21721.960	123	176.601		
	Total	22976.469	129	22976.469		

p< .05

In Table 5, the group variances of the self-efficacy perceptions of gifted students towards computational thinking skills are listed. Age F(4, 125) = .446, p< .05, grade level F(3, 126)= .367, p< .05, maternal education level F(5, 124) = 1.683, p< .05, father's education level, F(6, 123)= 1.184, p< .05 did not differ significantly in CTSSP.

Table 6 shows the data of the variables whose group variances do not show a homogeneous distribution. The results of the Kruskal-Wallis H test, which is one of the nonparametric tests used in the analysis of the variables whose group variances do not show homogeneous distribution, are listed. The Kruskal-Wallis H test was preferred because it is a powerful test for detecting differences between three or more independent groups.

Table 6 Kruskal-Wallis H Test Results According to Computer Usage Time of Students' Scores from CTSSP

	Computer usage time	n	Rank average	sd	χ^2	p
CTSSP total score	1 Year	22	54.32	5	11.456	.043
	2 Year	22	50.09			
	3 Year	17	64.94			
	4 Year	25	66.08			
	5 Year	20	82.75			
	6 Year or more	24	75.29			
	Total	130				

p< .05

When the data in Table 6 are examined, it is seen that gifted CTSSP scores differ according to the duration of computer use, χ 2 (df=5, n=130) = 11,456, p< .05. This finding shows that the duration of computer use has different effects on students' self-efficacy perceptions regarding computational thinking skills. When the mean rank of the groups is considered, the CTSSP score of the students who have been using computers for 5 years is the highest, followed by the groups of students who have been using computers for 6 years or more and for 4 years.

Table 7 shows the data of the variables whose group variances do not show a homogeneous distribution. The results of the Kruskal-Wallis H test, which is one of the nonparametric tests used in the analysis of the variables whose group variances do not show homogeneous distribution, are listed.

Table 7 Kruskal-Wallis H Test Results According to How Students Scores from the CTSSP Scale Define Computer Use Skills

	Computer skills	n	Rank average	sd	χ^2	p
CTSSP total score	A little bad	7	44.79	3	15.101	.002
	Some good	20	46.05			
	Good	69	64.47			
	Very good	34	83.29			
	Total	130				

p< .05

The data in Table 7 shows us that the CTSSP total scores of gifted students differ according to how they describe their computer use Skills, χ^2 (sd=3, n=130) = 15.101, p< .05. This result indicates that how students define their computer skills has different effects on CTSSP. When the mean rank of the groups is considered, it is seen that gifted students who define their computer use skills as very good have the highest self-efficacy perceptions towards computational thinking skills, followed by students who define themselves as good.

Findings of the third sub-problem

It was shown in Table 2 that gifted students had high ICTSEP levels ($\bar{X}$ =118.43). As seen in Figure 2, it can be stated that the ICTSEP scores are above the average.

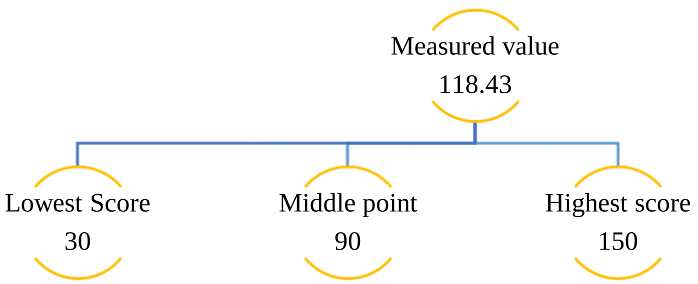

Figure 2 Demonstrating Participants' ICTSEP Levels

Findings of the fourth sub-problem

Table 8 shows the n-numbers, mean, standard deviation and t-test values of the scores that gifted students got from ICTSEP according to their school type, gender, having a room, and having a computer.

Table 8 Number of Participants, Mean, Standard Deviation and t-Test Values of the Scores Received from ICTSEP

Variables		N	X̄	SS.	*t*
School Type	State school	105	118.30	23.59	-.137
	Private school	25	119.00	19.08	
Gender	Female	78	115.74	22.25	-1.667
	Male	52	122.48	23.05	
Do you have room	Yes	107	120.31	21.57	2.058
	No	23	109.69	26.25	
Do you have computer	Yes	100	121.12	22.66	2.505
	No	30	109.50	20.91	

p< .05

As seen in Table 8, when the information technology self-efficacy perceptions of gifted students in terms of school type (t= -.137, p< .05) are analyzed, there was no significant difference between public schools (X̄=118.30, SD=23.59) and private schools (X̄=119.00, SS=19.08) groups. In terms of gender (t= -1.667, p< .05), no significant difference was found between female (X̄=115.74, SD=22.25) and male (X̄=122.48, SD=23.05) students, although the ICTSEP was higher for male students. In terms of whether the students have their own room (t= 2.058, p< .05), there was a difference between the groups of having a room of their own (X̄=120.31, SD=21.57) and not having a room of their own (X̄=109.69, SD=26.25). It was found that ICTSEP was higher in the direction of those with their own room and there was a significant difference. In terms of having a computer (t= 2.505, p< .05), there was a significantly high difference between those who have a computer (X̄=121.12, SS=22.66) and those who do not have a computer (X̄=109.50, SD=20.9).

A one-way ANOVA was conducted to determine whether there was a statistically significant difference between the total score of gifted students in ICTSEP with various variables. One-way ANOVA results are given in Table 9.

Table 9 ANOVA Results of Students' Scores from ICTSEP by Various Variables

Variables	Variance Source	Sum of Squares	sd	Mean Squares	F	p
Age	Between groups	1019.128	4	254.782	.485	.747
	In-group	65640.879	125	525.127		
	Total	66660.008	129			
Grade	Between groups	122.837	3	40.946	.078	.972
	In-group	66537.170	126	528.073		
	Total	66660.008	129			
Mother's education status	Between groups	1426.921	5	285.384	.542	.744
	In-group	65233.087	124	526.073		
	Total	66660.008	129			
BİLSEM Grup	Between groups	123.391	2	61.696	.118	.889
	In-group	66536.616	127	523.910		
	Total	66660.008	129			

p< .05

Table 9 lists the group variances of gifted students' information technology self-efficacy perceptions with homogeneous distribution. Age F(4, 125) = .747, p< .05, grade level F(3, 126)= .972, p< .05, maternal education level F(5, 124) = .744, p< .05, and BİLSEM group did not differ significantly F(2, 127)= .889, p< .05.

Table 10 shows the data of the variables whose group variances do not show homogeneous distribution. The results of the Kruskal-Wallis H test are given below.

Table 10 Kruskal-Wallis H Test Results According to Computer Usage Time of Students' ICTSEP Scores

	Computer using time	n	Rank average	sd	χ^2	p
ICTSEP total score	1 Year	22	49.70	5	19.488	.002
	2 Year	22	50.75			
	3 Year	17	51.41			
	4 Year	25	72.06			
	5 Year	20	84.90			
	6 Year or more	24	80.48			
	Total	130				

p< .05

When the data in Table 10 are examined, it is seen that the ICTSEP scores of the gifted students differ according to the time they use the computer χ^2 (sd=5, n=130) = 19.488, p<.05. This finding shows that the duration of computer use has different effects on students' information technology self-efficacy perceptions. When the mean rank of the groups is taken into account, the students who have been using computers for 5 years have the highest

ICTSEP, followed by the groups of students who have been using computers for 6 years or more and for 4 years.

Table 11 shows the data on how students define their computer use skills, among the variables whose group variances do not show a homogeneous distribution. The results of the Kruskal-Wallis H test are presented.

Table 11 Kruskal-Wallis H Test Results According to How Students' ICTSEP Scores Define Computer Use Skills

	Computer using skills	n	Rank average	sd	χ^2	p
ICTSEP total score	A little bad	7	35.21	3	32.883	.000
	Some good	20	43.58			
	Good	69	60.56			
	Very good	34	94.66			
	Total	130				

p< .05

The data in Table 11 shows us that gifted students' total scores on ICTSEP differ according to how they describe their computer use skills χ^2 (sd=3, n=130) = 32.883, p< .05. This result indicates that how students define their computer use skills has different effects on ICTSEP. When the mean rank of the groups is taken into account, it is seen that gifted students who define their computer use skills as very good have the highest self-efficacy perceptions towards computational thinking skills, followed by students who define themselves as good.

Findings of the fifth sub-problem

Pearson correlation coefficients of the scores were calculated to determine the relationship between the total scores and factors of the participants from the self-efficacy perception scale for computational thinking skills and the total score they got from the information technology self-efficacy perception scale. Analysis results are presented in Table 12.

Table 12 CTSSP, ICTSEP and Factors Total Scores Pearson Correlation Coefficients

Variables	CTSSP (Total)	ICTSEP (Total)
ICTSEP (Total)	.744	1
CTSSP (Total)	1	.744
F1. Algorithm design competence	.834	.577
F2. Problem solving competence	.690	.433
F3. Data processing competence	.842	.659
F4. Basic programming proficiency	.837	.743
F5. Self confidence competence	.802	.624

p< .05

When Table 12 is examined, in terms of total scores and factors; It was observed that there was a high level of positive correlation between ICTSEP total score and CTSSP total score (r=.744; p< .05). As for the relationship between ICTSEP and the factors, there was a positive correlation between ICTSEP total scores and Algorithm Design Competence (r=.577; p< .05), a positive correlation with Problem Solving Competence (r=.433; p< .05), a positive correlation with Data Processing Competence (r= .659; p< .05), a high level of positive correlation with Basic Programming Competence (r=.743; p< .05), and a high level of positive correlation with Self-Confidence Competence (r=.624; p< .05).

Conclusion, Discussion and Recommendations

In this study, the relationship between gifted students' self-efficacy perceptions for computational thinking skills and their information technology self-efficacy perceptions were examined. Accordingly, the results of the perception of self-efficacy towards computational thinking skills, the factors of this perception and its relationship with various variables, the perception of information technology self-efficacy, the relationship of this perception with various variables, and the connection between these two scales are presented.

In the study, it was determined that gifted students' self-efficacy perceptions towards computational thinking skills were above the average and high. In similar studies (Özel, 2019; Ramazanoğlu, 2021), it was stated that the self-efficacy perceptions of middle school students towards computational thinking skills are at a moderate level and that they can be increased with the training provided. The results obtained can be interpreted as the education and perception capacities of gifted students at BİLSEM increase these perceptions. In addition, it is seen that the sub-dimensions of perception of self-efficacy for computational thinking skills are above the average. The overall effect of the sub-dimensions on the total score is from large to small; problem solving competence, self-confidence competence, data processing competence, algorithm design competence, and basic programming competence. Wetzel et al. (2020) stated in their study that gifted students demonstrated advanced skills in algorithmic thinking, debugging and generalization, but remained at a basic level only in abstraction skills. In the literature, no ranking was encountered in terms of factors, but Kuleli (2019) stated that secondary school students taking the elective information technologies and software course in the seventh and eighth grades increased the scores of these factors. It can be said that individuals with high computational thinking skills can solve complex problems and use analytical thinking skills more effectively. For this reason, it has been stated that these individuals are generally more successful in finding creative and efficient solutions to complex problems (Alyahya & Alotaibi, 2019).

In the next stage of the study, the self-efficacy perceptions of gifted students towards computational thinking skills do not differ according to gender, age, class level, school type, education status of parents. On the other hand, there was a significant difference between the self-efficacy perceptions in terms of having a private room, owning a computer, computer usage time, and computer usage skills. Kuleli (2019) stated that this perception differs according to gender in her study with eighth-grade secondary school students, while Özel (2019) emphasized that gender does not have a decisive effect on this perception. It is thought that the change in the gender effect may be due to the place and class level of the students. Ma et al. (2021) examined the effect of a problem-solving-based teaching approach to improve computational thinking skills and self-efficacy perceptions among primary school students in China. It was determined that there was a significant difference in the computational thinking skills and self-efficacy perceptions of female students. While there is no research in the literature examining the effect of mother's education and father's education on this perception, there are studies that address the effects on students' computational thinking skills. In these studies, it is stated that the increase in the education level of parents increases the probability of encountering experiences and activities that increase their children's computational thinking skills (Sivrikaya, 2019; Yolcu, 2018). The self-efficacy perceptions of students for computational thinking skills, which change according to how many years they have been using computers, increase in direct proportion with the increase in time. This result is in parallel with the study by İbili and Günbatar (2019). Studies indicate that students' computer use for many years increases their computational thinking skills (Bilici & Güler, 2021; Totan, 2021). It can be said that increasing computational thinking skills will lead to an increase in the self-efficacy perception of the individual. In addition, the self-efficacy perception that increases according to how the person defines his/her computer skills is quite high in students who define themselves as very good computer users. This situation can be explained by the fact that the students know themselves and are aware of their abilities.

In the study, the information technology self-efficacy perception of gifted students was also analyzed, and it was observed that it was above the average. Similar results were obtained in studies conducted with different age groups in the literature. Taşdöndüren (2020) in her study with secondary school students states that students' past experiences and computer training increase their self-efficacy perceptions. In a similar study conducted with teachers and pre-service teachers, it is stated that the perception of information technologies self-efficacy increases depending on the individual's interest in and frequency of use of computers (Gurer et al., 2019; Sak & Demirer, 2014;). In their study with university students, Akçay and Çoklar (2018) stated that the level of information technology self-efficacy perception also affects the university department preferences of the students. However, it is thought that the perception of self-efficacy may depend not only on computer use but also on other factors such as the person's problem-solving skills, mathematical ability, and logical thinking ability. Therefore, it is emphasized that when evaluating a student's self-efficacy perception towards computational thinking skills, attention should be paid not only to the duration of computer use but also to the general skill level and experience (Labusch et al., 2019).

Within the scope of the study, it was observed that while the information technology self-efficacy perceptions of gifted students did not differ according to gender, age, class level, school type, or mother's education level, it increased according to whether they have a private room, computer usage, computer usage time, and computer usage skills. While it cannot be stated that there is a significant difference in the perception of information technology self-efficacy, which is higher in the direction of male students compared to gender, there are also studies in which the difference is at a significant level (Adsay et al., 2020; Dikmen & Çağlar, 2017). In the study examining the relationship between information technology self-efficacy and information technology acceptance, it is stated that basic computer knowledge and experience, social factors, using information systems and perceived usefulness have an effect on computational thinking (John, 2013). It is thought that this change may be due to variables such as the region where the application is made, the number of people, and age, and that the sample consists of gifted students. It has been concluded that the fact that the student has his/her own room and computer increases the information technology self-efficacy perception. In the literature, no results were found directly related to having one's own room and a computer. Eryılmaz et al. (2020) investigated the effect of family income on self-efficacy perception in their study with vocational high school students. They emphasized that having a computer that students can use whenever they want is important in increasing this perception. Le and Pinkwart (2019) reported that they spent a 10-week project experience with students in the Community of Gifted School Students in the Computer Science network they established and that the students demonstrated positive experience in the system analytics approach by implementing their own project ideas at the end of the semester. Another result that supports the aforementioned research is that the increase in the student's computer use time also increases the information technology self-efficacy perception. The study by Köroğlu and Demiriz (2015) reveals that the information technology self-efficacy perceptions of people change according to the age at which they first start using the computer and how many years they have been using the computer. In another study, it is stated that this perception decreases at young ages and in advancing ages (Korkmaz et al., 2019). In addition, the perception of self-efficacy, which changes according to how the person defines his/her computer skills, increases in students who define themselves as very good computer users. This self-evaluation of the student can be considered as an indicator of self-efficacy perception.

In this study, which examines the relationship between gifted students' self-efficacy perceptions for computational thinking skills and their information technology self-efficacy perceptions, there is a high level of self-efficacy for computational thinking skills between the information technology self-efficacy perceptions of the participants and their self-efficacy perceptions for computational thinking skills. It has also been concluded that there is a moderate relationship between the sub-dimensions of efficacy perceptions such as algorithm design competence, problem-solving competence, data processing competence, basic programming competence, and self-confidence competence. There is no study in the literature that directly examines this relationship. There are some studies addressing the relationship between information technology self-efficacy perception and factors. They stated that a high level of this perception positively affects students' proficiency in designing algorithms, increases their problem-solving skills and decreases problem avoidance behaviors, strengthens their skills to make sense of information and associate it with mental processes, increases their programming skills, and increases self-confidence (Alkan, 2019; Bakırcı, 2019; Bayırtepe & Tüzün, 2007; Hakkari et al., 2016; Mazman & Altun 2013; Uzun et al., 2010; Tuncer & Tanaş, 2011). These statements support the research results. It is stated that in evaluating students' computational thinking skills and self-efficacy perceptions towards information technologies, it may be useful for educators and researchers to understand students' attitudes towards computational thinking and the use of information technologies and to develop strategies that will make them feel more competent in these areas (Liao et al., 2022). However, the computational thinking process may differ in terms of students' readiness, motivation, teamwork, and peer communication (Tran, 2019).

Based on the results of this research, it has been shown that training and activities that will increase the information technologies and computational thinking skills of gifted students will increase their self-efficacy in these areas. These interrelated competencies can also create positive effects in interdisciplinary areas for students. In the research to be conducted in the future, the data collection tool used in such research of relational type, the amount of data collected and the evaluation method, the sample, and the variables may be differentiated, and their effects may be examined. The generalizability of the study can be increased by removing the dimension of gifted students, which is the focus of the study, and including all secondary school students. To support the quantitative aspect and reach more in-depth results, a qualitative dimension can be added to the research. By informing the stakeholders about the research results, its visibility and impact on the literature can be increased. It is recommended that researchers who will work in this field make applications, create good examples, and conduct studies that will increase students' information technologies and computational thinking self-efficacy.

Compliance with Ethical Standards

Disclosure of potential conflicts of interest

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Research involving Human Participants and/or Animals

The study involves human participants. Ethics committee permission was obtained from Balıkesir University, Science and Engineering Sciences Research Ethics Committee.

Özel Yetenekli Öğrencilerin Bilgi İşlemsel Düşünme Becerisine Yönelik Öz-Yeterlik Algıları ve Bilişim Teknolojileri Öz-Yeterlik Algıları İlişkisinin İncelenmesi

Özet

Günümüzde gelişen teknolojinin etkisi ve salgın hastalıklar gibi zorunlu sebepler nedeniyle eğitim ve öğretim faaliyetleri uzaktan eğitim yoluyla yapılabilmektedir. Çoğunlukla bilgisayar, tablet ve internet gibi teknolojik araçlarla gerçekleştirilen bu etkinliklerin etkili olabilmesi için öğrencilerin ihtiyaçlarına ve değişen özelliklerine hitap edebilmesi gerekmektedir. Bu bağlamda araştırmanın amacı üstün yetenekli öğrencilerin bilişimsel düşünme becerilerine ilişkin öz yeterlik algıları ile bilişim teknolojileri öz yeterlik algıları arasında bir ilişki olup olmadığını incelemektir. Örneklemi 2020-2021 eğitim-öğretim yılında Balıkesir ili Bilim ve Sanat Merkezlerinde uzaktan eğitim yoluyla öğrenim gören 130 ortaokul öğrencisinden oluşmaktadır. Yapılan analizler sonucunda üstün yetenekli öğrencilerin bilişimsel düşünme ve bilişim teknolojileri öz-yeterlik algılarının ortalamanın üzerinde olduğu ve aralarında yüksek düzeyde pozitif korelasyon olduğu görülmüştür.

Anahtar kelimeler: Özel yetenekli öğrenciler, bilişimsel düşünme, bilgi teknolojileri öz yeterliliği.

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Research Article

Preservice Teachers' Attitudes Toward Teacher Field Knowledge Test: Scale Development Study

Fahrettin AŞICI[1]

[1]Balıkesir University, Necatibey Faculty of Education, Türkiye,
fahrettin.asici@balikesir.edu.tr, https://orcid.org/0000-0002-7329-6418

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Abstract – Selecting teachers is a crucial aspect of the educational environment. Teacher employment in our country is carried out in line with the "Public Personnel Selection Exam (PPSE)". Until 2013, in the PPSE model, which measures teacher competencies with "General Culture", "General Ability" and "Educational Sciences" tests, the "Teacher Field Knowledge Test (TFKT)" has started to be applied in some branches since 2013. This study aims to develop a measurement tool to determine the attitudes of preservice teachers to TFKT. The scale was applied to 291 teacher candidates to test its validity and reliability. Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were used to gather evidence regarding construct validity. As a result of the analysis, it was found that the scale had a structure with 15 items and three factors and that the scale explained 59.309 % of the total variance. To determine the reliability of the scale, the Cronbach-Alpha internal consistency coefficient was calculated, and it was found that the Cronbach-Alpha internal consistency coefficient was .894 for the test and between .700 and .883 for each factor. With the confirmatory factor analysis, the three-factor structure was verified. In this context, the findings show that the scale measures pre-service teachers' attitudes towards TFKT in a valid and reliable way.

Keywords: Teacher field knowledge test, preservice teacher, scale development, attitude.

Corresponding author: Fahrettin AŞICI, fahrettin.asici@balikesir.edu.tr.

Introduction

Today, education is considered one of the basic elements that shape the development of societies. Educational scientists, who see education as a social system, accept that three basic elements of the education system are teacher, student, and curriculum. All the literature studies on the location and importance of these elements agree on the strategic importance of the teacher in the system. Regardless of the level, the training, selection of the teacher, and providing a qualified professional formation are constantly critical issues on the agenda (Eraslan, 2006).

In this context, considering the success and quality of education, it is seen that teacher selection has an important place because the qualification system for selection, appointment, and induction is as decisive as the quality of teacher education. It is especially important to carefully examine all the qualifications of teachers who will start working as practitioners in schools and to select teacher candidates with a high level of professionalism (Yağcı & Kurşunlu, 2017).

Candidates who meet the required conditions and receive the highest score in all election conditions should be hired in the teaching profession. Accordingly, the main objective of an effective teacher selection process should be to choose the right instructor personnel to perform an effective teaching activity.

Table 1 General Competencies for the Teaching Profession

A. Professional Knowledge	
A1. Content Knowledge	She/he has an advanced and critical perspective on theoretical, methodological, and factual knowledge in his/her subject field.
A2. Pedagogical Content Knowledge	She/he has a good knowledge of the curriculum and pedagogical content knowledge of her/his subject area.
A3. Knowledge on Legislation	As an individual and teacher, she/he conducts her/himself according to the legislation related to her/his duties, rights, and responsibilities.
B. Professional Skills	
B1. Planning of Education and Teaching	She/he plans education and teaching processes effectively.
B2. Creating Learning Environments	She/he prepares appropriate teaching materials and builds a healthy and safe learning environment, where effective learning can be achieved for all students.
B3. Managing the Teaching and Learning Process	She/he manages the teaching and learning process effectively.
B4. Assessment and Evaluation	She/he uses the methods, techniques, and tools of assessment and evaluation that fit for purpose.

C. Attitudes and Values	
C1. National, Moral and Universal Values	She/he observes national, moral, and universal values.
C2. Approach to Students	She/he has an attitude that supports the development of students.
C3. Communication and Cooperation	She/he establishes effective communication and cooperation with students, colleagues, families, and other educational stakeholders.
C4. Personal and Professional Development	By carrying out self-appraisal she/he participates in personal and professional development activities.

The first purpose of a reliable teacher selection process is to determine the teacher who will provide an effective educational service and have the qualifications to fulfill the task (Tösten et al., 2012). The general competencies of the teaching profession determined by the Ministry of National Education (MoNE), taking into account the required qualifications, are given in Table 1 (MoNE, 2017).

In this context, higher education institutions that train teachers in our country aim to train teachers with specified qualifications. Just as teachers should be given training to gain competencies in higher education, it will be inevitable to implement an examination system for the competencies that should be included in the selection of teachers (Yılmaz et al., 2018).

Various applications are made to employ the graduates of the departments that constitute the source of the teaching profession in Türkiye to be employed as teachers in the Ministry of National Education. Teacher selection has been carried out with various exams that emerged due to the supply-demand understanding that the Ministry of National Education applied from the past to the present day: “Teaching Proficiency Exam”, “Civil Service Exam”, “Public Vocational Examination”, and “Public Personnel Selection Exam (PPSE)” since 2002 (Deryakulu, 2011).

According to the PPSE conducted between 2002 and 2012, the candidates applying for the "Teaching" positions in the Ministry of National Education are required to take the "General Culture" and "General Ability" tests in the Saturday morning session and the "Educational Sciences" test in the Saturday afternoon session. In this context, the scores of the candidates in this exam were calculated by using 30% of the "General Culture" test, 30% of the "General Ability" test, and 40% of the "Educational Sciences" test. When the tests are examined in terms of content, it is seen that the "General Culture" test includes Atatürk's principles and history of the Turkish Revolution, the geography of Türkiye, basic citizenship knowledge, general and current socioeconomic issues related to Türkiye, and the world, and Turkish culture and civilizations. In the “General Ability” test, there are issues related to

Turkish and mathematics and in the “Educational Sciences” test there are subjects related to educational psychology, guidance, program development, and teaching (Centre for Assessment, Selection and Placement [OSYM], 2012).

On the other hand, such exams, which are applied as a selection and appointment system at the end of the teacher training process, are criticized by many groups regardless of their quality. One of the main criticisms is whether the test method used in teacher selection measures all the qualities that a teacher should have (Gündoğdu et al., 2008).

In today's conditions where the qualifications expected from teachers are diversifying day by day, the purpose of this exam should be to select the best teachers with the desired qualifications (Atav & Sönmez, 2013) because according to Article 43 of the Basic Law on National Education No. 1739 and Article 3 of the Professional Law No. 7354, "Teaching is a specialized profession that takes over the education, training and related administrative duties of the state. Preparation for the teaching profession is provided by general culture, field education, and pedagogical formation/teaching professional knowledge". In this context, considering the content of the PPSE applications carried out between 2002 and 2012, and the general competencies of the teaching profession in Table 1, the exams applied for teacher selection are not sufficient and comprehensive. Similarly, Baştürk (2007) stated that the lack of questions about field education in PPSE created a disconnection between the “field knowledge and field education" in the faculties of education and PPSE.

In this context, in the press release of the Measurement, Selection, and Placement Center dated December 10, 2012, it was announced that in some branches (Turkish, Primary Mathematics, Science and Technology, Social Sciences, Turkish Language and Literature, History, Geography, Mathematics, Physics, Chemistry, Biology, Religious Culture and Ethics, Foreign Language (English, German, French) "General Ability", "General Culture" and "Educational Sciences" tests as well as "Teaching Field Knowledge Test (TFKT)" will be applied. MoNE explained that the purpose of the exam is to ensure that good teachers are trained in terms of field and to assign individuals who have sufficient knowledge in their fields. When the amendment is examined in this context, it can be stated that the ministry wants to select candidates who have in-depth knowledge and skills about the subjects in the curriculum of their branch and who are competent in how the subjects in their field should be taught (Demir & Bütüner, 2014). In the following years, Guidance, Classroom Teaching, and Preschool Teaching were added to the branches to which the exam was applied. On the other hand, the scores of prospective teachers who took the TFKT were calculated by giving 15% to the "General Culture" test, 15% to the "General Ability" test, and 20% to the "Educational Sciences" test. It was also stated that the ratio of TFKT in the exam score would be 50% and that there would be a content knowledge test and a pedagogical content knowledge test in the application (OSYM, 2013).

Considering the ratio of the TFKT in the calculation of the scores based on appointment, it is seen that this test is very important for preservice teachers. As it is known, the placement of preservice teachers who want to work in state positions can be realized according to the success achieved in PPSE. For this reason, one of the most critical points for preservice teachers who graduate from education faculties is PPSE that awaits them after graduation (Odabaş, 2010) because PPSE plays a decisive role in the selection and employment of teachers for their lives (Atav & Sönmez, 2013). In this context, it is important to investigate the views of preservice teachers on the “Public Personnel Selection Examination” in general and the “Teacher Field Knowledge Test” in particular. In this context, when the relevant literature is examined, it is seen that the opinions and perceptions of preservice teachers from different branches towards PPSE have been examined (Atav & Sönmez, 2013; Epçaçan, 2016; Gündoğdu et al., 2008; Odabaş, 2010; Tösten et al., 2012; Yılmaz & Yaşar, 2016; Yağcı & Kurşunlu, 2017) and there have been various studies examining the opinions, perceptions and participation experiences of preservice teachers from different branches towards TFKT (Çelik, 2016; Demir & Bütüner, 2014; Dere & Demirci, 2022; Recepoğlu et al., 2016; Şahin & Demir, 2016; Şahin et al., 2017;). In addition, there is a scale for determining the views of primary school teachers towards PPSE developed by Tösten in 2011 and a study by Yılmaz et al. (2018) to develop a perception scale for visual arts teacher candidates regarding PPSE. In this sense, the number of measurement tools that can be used in studies on TFKT, which has an important place for preservice teachers, is limited.

In this context, the present study aims to develop a measurement tool to reveal preservice teachers' attitudes toward the “Teaching Content Knowledge Test”. The resulting scale will likely be a guide for researchers who want to measure preservice teachers' attitudes in this field.

Method

The research is a scale developmental study. The stages of developing the scale prepared to determine the attitudes of pre-service teachers towards the "Teacher Field Knowledge Test" and the characteristics of the study group are given below.

Participants

The study group of this study consisted of 291 preservice teachers from different branches (Primary School Mathematics Teaching, Mathematics Teaching, Primary Teaching, Science and Technology Teaching, Social Sciences Teaching, and English Language Teaching) studying at the faculty of education of a state university located in the Central Anatolia Region of Türkiye. In determining the study group, the requirements of the preservice teachers to study in the last grade and to take TFKT within the scope of the PPSE application of the branches to be selected were taken into consideration. Although there are different opinions on what the sample size should be in scale development studies, it is frequently emphasized in the literature that a sample size of 5-10 times the total number of items in the scale (Tavşancıl, 2014) or a sample size of at least 10 times the number of items is required to determine the sample size in reliability and validity analyses (DeVellis, 2003; Tabachnick & Fidell, 2015). In this context, it can be said that the number of preservice teachers in the study group is sufficient for this study.

Development of the Item Pool

During the preparation of the item pool for the scale, first, the studies on preservice teachers, PPSE, and TFKT were examined in the literature and the indicators related to the variables were determined. In this context, attitude scales in the literature and studies examining pre-service teachers' views and perceptions of PPSE and TFKT practices were utilized.

Accordingly, an item pool of 30 items was created. As a result of the evaluation of two experts in the field of measurement and evaluation and an expert in the field of Turkish Education, 6 items were removed from the prepared draft scale, taking into account the fact that the items were not sufficiently understandable, contained more than one situation, and did not contain attitude expressions, and a draft scale form with 24 items was created. Eleven of the items in the draft scale consist of negative and 13 positive sentences. This five-point Likert-type draft scale was graded as strongly agree (5), agree (4), undecided (3), disagree (2), and strongly disagree (1). Before the factor analysis, the scores of the negative items were reversed.

Data Analysis

The analyses conducted to provide evidence for the reliability and validity of the Attitude Scale for the Teacher Field Knowledge Test (ASTFKT) can be listed as follows:

“Exploratory Factor Analysis (EFA)” and “Confirmatory Factor Analysis (CFA)” were conducted to provide evidence for the construct validity of the scale. The type of analysis in which the researcher has no information about the number of factors measured by the measurement tool and tries to obtain information about the nature of the factors measured by the measurement tool instead of testing a certain hypothesis is defined as exploratory factor analysis, and the type of analysis used in examinations to test a hypothesis developed by the researcher in line with the theory is defined as confirmatory factor analysis (Tavşancıl, 2006). In line with the EFA conducted in the SPSS package program, it was revealed which factors the items in the scale were related to. At this stage, principal component analysis, Kaiser Meyer Olkin test (KMO), and Barlett's test of Sphericity methods were used to determine the suitability of the data. The Varimax technique was used to obtain the factors. On the other hand, the LISREL package program was used for CFA and the suitability of the model revealed in EFA was checked by looking at various values in this analysis. In addition, Cronbach Alpha coefficients were calculated for the reliability of the total scale and the sub-factors that make up the scale.

Results

In this section, the findings related to the validity and reliability studies conducted for the "Attitude Scale for the Teacher Field Knowledge Test" are presented.

Findings Related to Validity

Principal component analysis was performed to reveal the data on the construct validity of the developed attitude scale and the factors loaded by the items. Kaiser-Meyer-Olkin (KMO) coefficient and Barlett's test of Sphericity values were calculated for the suitability of the data for principal component analysis (KMO= .918; χ^2=1832.654; sd=105; p<.00). Kaiser (1974) states that factor analysis can be performed if the KMO value is higher than 0.5. The fact that the results of the Barlett test are significant reveals that there are significant relationships between the variables and that the data come from a multivariate normal distribution (Bartlett, 1950). In this direction, it can be stated that the data of the trial form of the scale are suitable for factor analysis.

As a result of the first EFA, it was seen that the scale items were grouped under four factors with eigenvalues greater than 1, and the variance explained by these four factors was 58.080%. Since it was stated that the factor loading should be at least .40 for an item to be included in a factor (Floyd & Widaman, 1995; DeVellis, 2003) and there should be a minimum difference of .20 between the factor loading values of the items loading on more than one factor (Howard, 2016), at this stage, some items with a loading value below .40 and items loading on more than one factor were removed from the scale and EFA was repeated. As a result of the analyses, a final scale form of 15 items consisting of 3 factors was obtained. The eigenvalues of these factors are presented in Figure 1 and Table 2. In addition, the three-factor structure obtained from the exploratory factor analysis was tested by examining the Scree Plot graph. When Figure 1 is examined, it is seen that the break and slope lines are more prominent along the first three factors, while the graph progresses more horizontally from the third factor onwards.

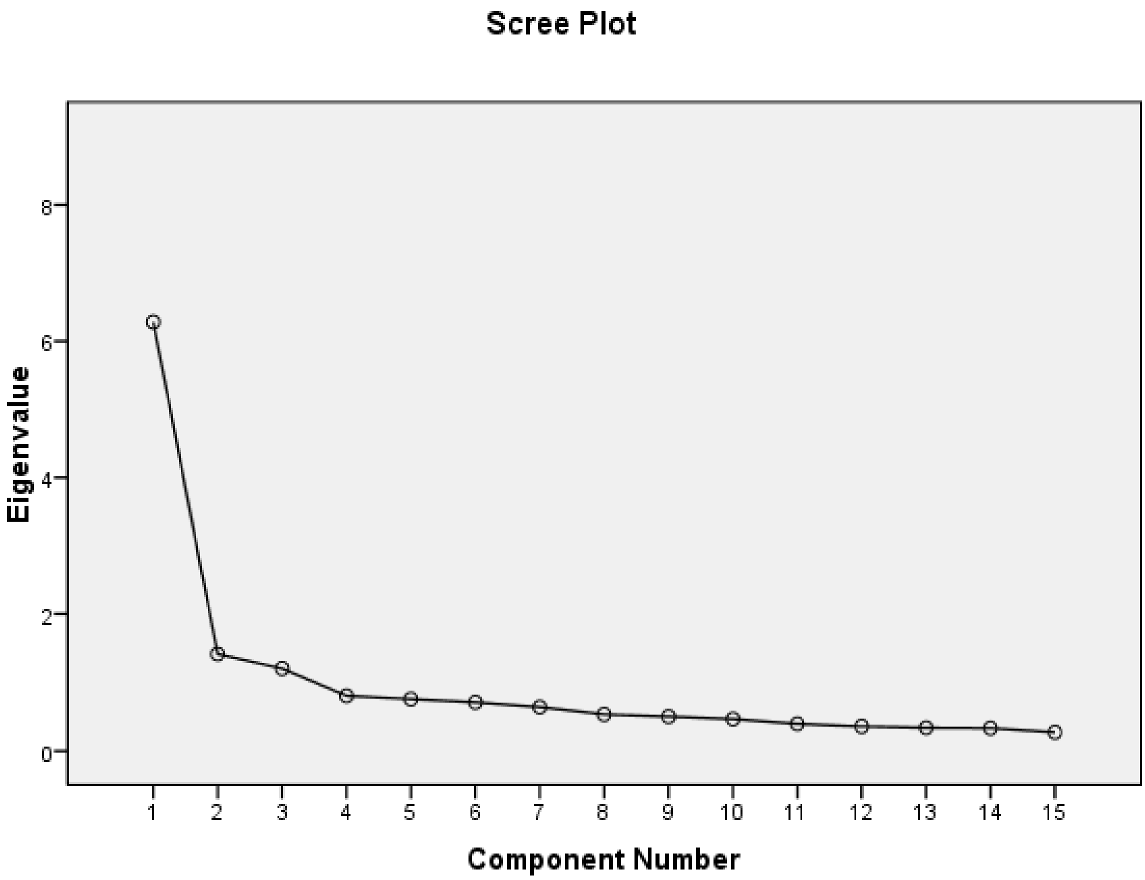

Figure 1 Scree Plot Graph Obtained from EFA

The factor loading values and explained variance ratios obtained as a result of the exploratory factor analysis conducted within the scope of the study to develop ASTFKT for preservice teachers are presented in Table 2.

According to the EFA data in Table 2, the final 15-item scale was grouped into 3 factors, the first factor consisted of 6 items (I1, I2, I7, I8, I10, I23) with loadings ranging from .637 to .846, the second factor consisted of 5 items (I3, I9, I15, I17, I21) with loadings ranging from .613 to .777, and the third factor consisted of 4 items (I12, I19, I22, I24) with loadings ranging from .600 to .748. In addition, the first factor with an eigenvalue of 6.280 and explained variance of 41.864% was named as "Positive Attitude towards Discrimination of TFKT", the second factor with an eigenvalue of 1.415 and explained variance of 9.434% was named as "Negative Attitude towards Application of TFKT" and the third factor with an eigenvalue of 1.202 and explained variance of 8.011% was named as "Negative Attitude towards Format of TFKT". It is also seen that all sub-dimensions of the scale explained 59.309% of the total variance.

Table 2 EFA Values Related to the Factors of ASTFKT

	Items		Factor 1	Factor 2	Factor 3
Factor 1	I1	A good teacher is one who is successful in TFKT.	.758		
	I2	A PPSE including TFKT is the right exam for selecting teachers.	.684		
	I7	I think that TFKT fills the gaps in the previous exams.	.718		
	I8	TFKT distinguishes between those who deserve to be teachers and those who do not.	.846		
	I10	TFKT is an exam that distinguishes pedagogically good candidates.	.778		
	I23	The results of TFKT are successful in distinguishing a good teacher.	.637		
Factor 2	I3	In addition to the "General Ability", "General Culture" and "Educational Sciences" tests, the TFKT is unnecessary.		.654	
	I9	A PPSE without TFKT would be better.		.689	
	I15	PPSE without TFKT is a sufficient test for teacher appointments.		.777	
	I17	TFKT is one of the obstacles in getting my life on track.		.613	
	I21	I would abolish TFKT if I could.		.616	
Factor 3	I12	I do not think prospective teachers who get high scores in TFKT are good in fact.			.620
	I19	I do not find it right to measure content knowledge and pedagogical content knowledge with multiple-choice questions.			.748
	I22	I do not believe that TFKT measures teacher competencies.			.627
	I24	I would prefer a different format exam instead of TFKT.			.600
		Eigenvalue:	6.280	1.415	1.202
		Explained Variance:	41.864	9.434	8.011
		Total Explained Variance:		59.309	

In the next stage of the study, the results obtained from the exploratory factor analysis were tested with "Confirmatory Factor Analysis" to examine the construct validity of the model, and satisfactory results were obtained. Figure 2 shows the factor distributions and loading values of the CFA.

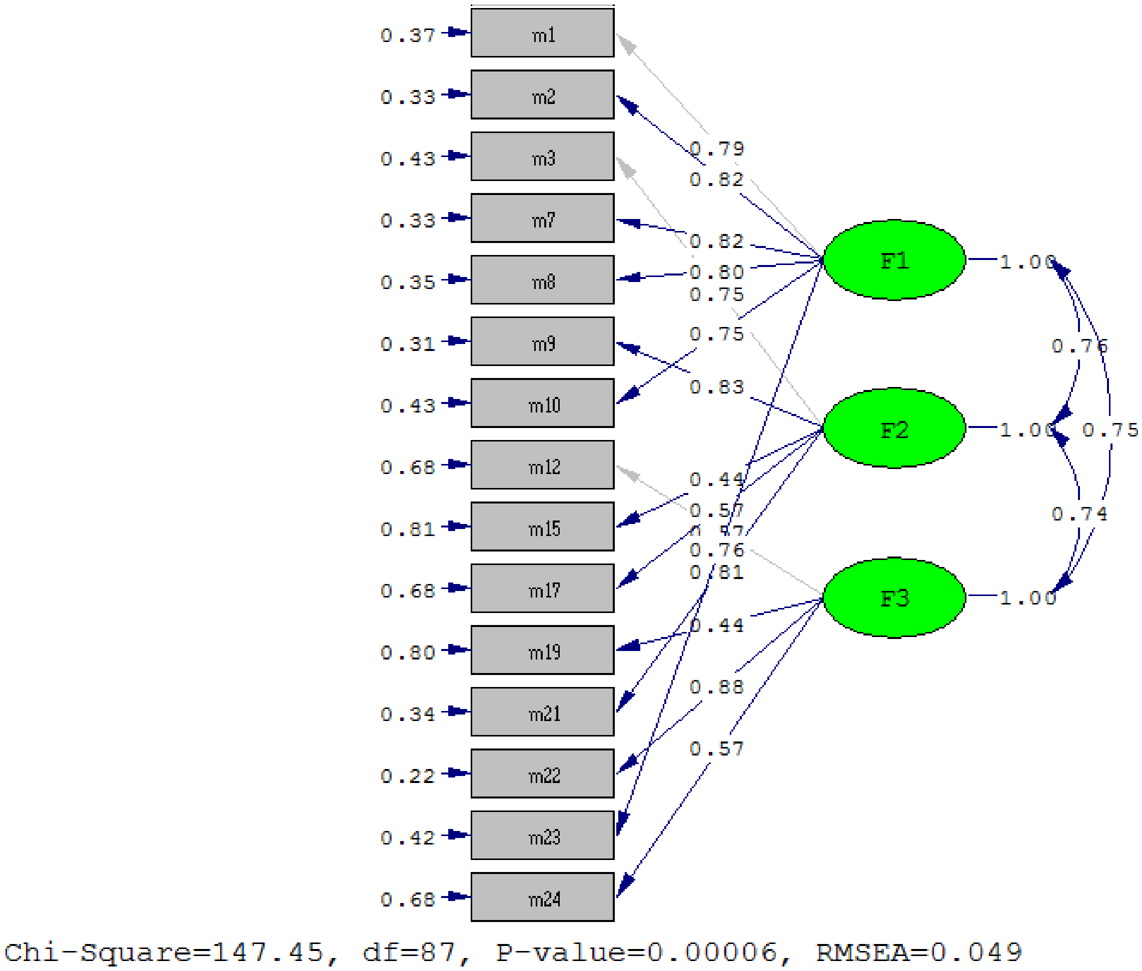

Figure 2 Path Diagram Obtained as a Result of Confirmatory Factor Analysis

When the model given in Figure 2 is examined, the error variances of the items and the factor loading values of the factors that the items are related to are seen. Accordingly, it can be stated that the correlation values between the items and the factors they are related to are between .44 and .88, the relationship between factor 1 and factor 2 is .76, the relationship between factor 1 and factor 3 is .75, and the relationship between factor 2 and factor 3 is .74. On the other hand, the chi-square, chi-square/degrees of freedom and fit indices values of this model with CFA were calculated as χ^2=147.45, sd=87, χ^2/sd=1.69, p=.00, RMSEA= .049, GFI= .90, AGFI= .85, NFI= .97, NNFI= .99, CFI= .99 and IFI= .99.

It was seen that the t-values examined to determine whether the item standardization and decomposition of rates related to CFA were significant or not ranged between 2.31 and 9.52. In this context, the calculated t values were found to be significant at p<.05 level for all items.

As a result, it can be said that there was no need for any modification in the confirmatory factor analysis and that the 15-item measurement tool showed a good fit and was applicable in the context of the fit index values obtained after CFA.

Findings Related to Reliability

Cronbach Alpha internal consistency coefficients were calculated for the reliability of the scale during the development process of the "Attitude Scale for the Teacher Field Knowledge Test". Accordingly, the Crα coefficient for the first factor of the scale, "Positive Attitude towards Discrimination of TFKT" was calculated as .883, for the second factor, "Negative Attitude towards Application of TFKT" as .793, and for the third factor, "Negative Attitude towards Format of TFKT" as .70. Cronbach's alpha coefficient for the whole scale was calculated as .894.

Conclusions and Suggestions

In this study, a scale, aiming to measure preservice teachers' attitudes towards the "Teacher Field Knowledge Test" was developed. Within the scope of the literature review conducted during the development of the scale, a draft scale was prepared by considering the studies on preservice teachers' thoughts and perceptions about PPSE and TFKT, and then this scale was applied to preservice teachers. The study was conducted to determine the validity and reliability of the model based on the data obtained after the application.

When the reliability results of the scale are examined, the reliability coefficients of the three factors in the scale and the overall scale are .70 or higher, indicating that the scale has an acceptable level of reliability (Nunnally, 1978).

On the other hand, construct and content validity were also examined for the validity of the scale. Expert opinion was used to determine the content validity of the developed scale, and exploratory and confirmatory factor analyses were used to test the construct validity. As a result of the exploratory factor analysis, it was determined that the scale had a three-factor structure and the three factors explained 59.309% of the total variance. Accordingly, the scale factors were named as "Positive Attitude towards Discrimination of TFKT", "Negative Attitude towards Application of TFKT", and "Negative Attitude towards Format of TFKT". In addition, the fit indices obtained from the confirmatory factor analysis conducted to verify the three-factor 15-item structure were found to be at an acceptable level. In this context, based on the EFA and CFA results, it can be said that this three-factor scale has a valid structure.

In summary, it was concluded that the items of the developed attitude scale both served to measure the desired characteristic and were able to distinguish between the pre-service teachers who had the desired characteristic and those who did not.

In the research conducted by Uyulgan and Akkuzu (2015), preservice teachers' expectations and negative opinions towards the TFKT were examined. As a result of the study, items such as the need for the test to be selective and discriminative came to the fore. In addition, it was also stated that preservice teachers consider the field knowledge exam necessary in terms of distinguishing between those who know and those who do not know, having a high score ratio, and ensuring the selection of a qualified teacher. Similarly, in the study conducted by Demir and Bütüner (2014), the opinions of preservice teachers on the field knowledge test were examined, and two themes were identified: findings on the content of the field knowledge test and test overall, and findings on the validity and reliability of the field knowledge test. Şahin et al. (2017) examined the opinions of pre-service preschool teachers about the field exam. In light of the data obtained in this study, the findings were analyzed under themes such as the necessity, content, and distinguishing power of the field exam. Shortly, it is possible to state that the factors of the scale obtained are consistent with the findings of other studies.

Teacher Field Knowledge Test was introduced within the scope of PPSE in 2013. However, no study has been conducted to measure the attitudes of preservice teachers towards this test or to develop a measurement tool to measure their attitudes. Nevertheless, it is important to investigate the attitudes of preservice teachers towards this exam to reveal the current situation and to relate it to the previous format of PPSE. Although attitude is a phenomenon that does not change quickly, it is a process that is not impossible to change (Keçeli, 2007). Therefore, it would be appropriate to apply the developed scale to measure the attitudes of preservice teachers during their undergraduate education.

In line with the results of this study, it may be recommended to conduct comparative studies in different branches and grade levels by applying the attitude scale obtained as a result of the study. In addition, it may also be recommended to conduct studies on determining the relationship between the attitudes of pre-service teachers and a different variable.

Compliance with Ethical Standards

Disclosure of potential conflicts of interest

There was no conflict of interest in this study.

Funding

None.

CRediT author statement

This is a single-author study.

Research involving Human Participants and/or Animals

This research involves human participants. The data for the study was collected before 2020. According to the TR Index Ethical Rules, retrospective ethics committee approval is not required for studies that used research data before 2020. Therefore, no ethics committee permission application was made within the scope of this study. However, the necessary permissions were obtained from the authorities of the relevant faculty of the state university where the study would be collected by conducting the necessary interviews regarding data collection.

Öğretmen Adayları İçin Öğretmenlik Alan Bilgisi Testine Yönelik Tutum Ölçeği Geliştirme Çalışması

Özet:

Eğitim-öğretim ortamının temel faktörlerinden biri olan öğretmenlerin, seçimi de oldukça önemlidir. Ülkemizde öğretmen istihdamı “Kamu Personeli Seçme Sınavı” doğrultusunda yapılmaktadır. 2013 yılına kadar “Genel Kültür”, “Genel Yetenek” ve “Eğitim Bilimleri” testleri ile öğretmen yeterliliklerini ölçen KPSS modelinde, 2013 yılından itibaren “Öğretmenlik Alan Bilgisi Testi” de bazı branşlarda uygulanmaya başlanmıştır. Bu çalışmanın amacı, öğretmen adaylarının ÖABT’ye yönelik tutumlarını belirlemeye yönelik ölçme aracı geliştirmektir. Geliştirilen ölçeğin geçerliği ve güvenirliğini test etmek için 291 öğretmen adayına uygulama yapılmıştır. Yapı geçerliğine kanıt toplamak amacıyla “Açımlayıcı Faktör Analizi (AFA)” ve “Doğrulayıcı Faktör Analizi (DFA)” yapılmıştır. Yapılan analizler sonucunda ölçeğin 15 madde ve üç faktörlü bir yapıya sahip olduğu ve ölçeğin toplam varyansın % 59.309’unu açıkladığı saptanmıştır. Ölçeğin güvenirliğini belirlemek amacıyla ayrıca Cronbach-Alpha iç tutarlılık katsayısı hesaplanmıştır. Cronbach-Alpha iç tutarlılık katsayısının ölçeğin tamamı için .894, her bir faktör için ise .700 ile .883 arasında olduğu görülmüştür. Yapılan doğrulayıcı faktör analizi ile de üç faktörlü yapı doğrulanmıştır. Bu bağlamda elde edilen bulgular ölçeğin, öğretmen adaylarının ÖABT’ye yönelik tutumlarını geçerli ve güvenilir bir şekilde ölçtüğünü göstermektedir.

Anahtar kelimeler: Öğretmenlik alan bilgisi testi, öğretmen adayı, ölçek geliştirme, tutum.

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Research Article

Investigating Classroom Teachers' Experiences on the Use of Digital Stories*

Şuheda ÜNAL[1], Osman ÇİL[2]

[1] Ministry of National Education, Yunus Emre Primary School, Türkiye, unallsuhedaa97@gmail.com, https://orcid.org/0000-0003-0481-5760

[2] Kırşehir Ahi Evran University, Faculty of Education, Türkiye, ocil@ahievran.edu.tr, https://orcid.org/0000-0001-5903-9864

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Abstract – This study aimed to investigate classroom teachers' experiences with the use of digital stories in the mathematics teaching process by using the phenomenological research design. Digital stories and lesson plans prepared by the researcher for each primary school grade mathematics course were distributed to the participating teachers during the data collection process. Teachers were asked to teach their lessons with the digital story appropriate for the grade level. The classroom teachers stated that teaching mathematics with digital storytelling provided concretization of abstract concepts, ensured retention, increased attention towards the lesson, and facilitated the transfer of what they learned to real life. The danger of turning the use of technology into a habit, the hardship of preparing digital story materials that could address students' individual differences, insufficient technological equipment in the teaching environment, and problems related to the time-consuming nature of the practice were the main disadvantages of teaching mathematics via digital stories.

Keywords: Digital story, mathematics teaching, classroom teachers.

Corresponding author: Şuheda ÜNAL, unallsuhedaa97@gmail.com.

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*This study was produced from the master's thesis of the first author. A part of this study was presented as an oral presentation at the 2nd International Educational Sciences Congress.

Introduction

Since ancient times, traditional storytelling has played an important role in the transfer of knowledge, beliefs, values, history, culture, and traditions to other individuals, communities and future generations (Smeda et al., 2014; Wang & Zhan, 2010). According to Meadows (2003), as a form of import, traditional storytelling is one of the important tools used throughout history in the transfer of knowledge, wisdom and values. Storytelling is a natural way of communication to enable people to better perceive intertwined thoughts, concepts, and information (Chung, 2006; Mello, 2001). As in every literary work, each story carries a certain point of view based on specific feelings and thoughts and shortly expresses the message it wants to convey around various events (Bull & Kajder, 2005). Many researchers agree that storytelling is essential to perceive how people understand and organize information (Si, 2016).

In the present era, stories have been digitized with the development of technology and audio, music, visual, photograph, and video elements are added to the story, so the stories have been transferred to digital media as digital stories (Kurudayıoğlu & Bal, 2014). With the change and development in technology, new tools and concepts emerged such as computers, tablets, smart boards, and internet technologies, therefore teaching needs are differentiated (Alakoç, 2003). Students growing up in the digital environment readily adopt technology as a tool for learning because technological environments appeal to multiple sensory organs (France & Wakefield, 2011). Demir (2019) similarly mentions the importance of using technology in education because digital tools are a part of children's lives, textbooks have turned into interactive books, and communication is provided online. The nature of storytelling has changed and the transfer of storytelling to the digital media environment has begun with the development and increasing use of information technologies and the emergence of different hardware and software (Kaya Erdem & Baydaş Sayılgan, 2011; Van Gils, 2005). Digital stories that emerged with the effect of the development of current technology are among the materials used while integrating information and communication technologies into the learning environment (Pürbudak & Usta, 2019).

Related Studies In The Literature

A digital story is a the combination of a story with multimedia environments such as images, videos, graphics, text, sound, and music to provide information about a subject (Robin, 2006). İnceelli (2005) defines digital storytelling as a process of preparing a short film of 2-6 minutes, in which the story writer usually dubs the story himself/herself and utilizes multimedia tools such as visual, video, and music. The author emphasizes that a new perspective is given to the digital story method by integrating the traditional storytelling method with technology. Ohler (2008) describes digital storytelling as a unique process created by combining traditional storytelling with media tools such as computers, video cameras, and sound recorders.

It is emphasized that the digital story method can provide education and training opportunities that can meet the needs of the century we live in and improve individuals' skills regarding the analysis of visual and auditory data, meaningful learning, prediction, and liberal thinking skills. In addition, it is believed that the digital story method will cause significant changes in education and is a different, highly functional and unique method for the generation called the digital natives (Bozdoğan, 2012). A digital story is an educational tool recommended for teachers and students at all levels from preschool to higher education in gaining and developing communication, research and cooperative learning skills (Di Blas et al., 2009; LaFrance & Blizzard, 2013).

The digital storytelling method is believed to assist individuals in analyzing, learning, and evaluating current problems and improving their creativity and it is argued that this method is different, original, and functional for the next generations that will shape the future of education (Bozdogan, 2012). In addition, Barrett (2005) emphasized that digital stories facilitate the aggregation of four student-based learning methods, cited as the active participation of the student, reflection for learning, project-based learning, and the active transfer of technology to the learning environment. In addition, integrating digital stories into the learning environment increases students' school achievement, enables them to develop positive behaviors about the course, improves their writing, critical thinking, and problem-solving skills, and provides them with the opportunity to ensure permanence in learning and express themselves (Balaman, 2016a; Foley, 2013; Robin, 2006; Tatlı & Aksoy, 2017; Yoon, 2013).

Kurtoğlu Erden and Uslupehlivan (2016) underlined that digital stories can be used in almost every part and level of education and argued that the process should be well planned for active and efficient use in the teaching environment, which requires mastery of the features of the digital story approach by teachers. Teachers who can benefit from the superior aspects of the digital story method can direct their students to cooperative learning and to interact with people inside and outside the classroom with digital stories (Kocaman Karoğlu, 2015). Teachers who can actively use technology in education are the most important element of the digital story-creation process which includes certain elements, sequences, and processes (Haliloğlu Tatlı, 2016; Kahraman, 2013; Karakoyun, 2014; İnceelli, 2005).

Digital story is one of the leading teaching methods of the age in conveying information to digital natives and accommodating to them (Çoruk & Seferoğlu, 2020). Integrating technology into education is often thought to be an important tool to make students active in complicated mathematics learning environments (Zbiek et al., 2007). In addition to the use of digital storytelling in reading, writing, and language education, researchers have emphasized the importance of using digital storytelling in mathematics teaching (Küçükoğlu, 2019). Although educators focus more on developing students' reading, writing and language skills, problem-solving skills should also be developed in this era (İncikabı, 2015). Digital storytelling can enrich teaching by attracting attention in mathematics education (Schiro, 2004). Doing research on the subject with the digital storytelling method improves students' analysis, creation, and critical thinking skills (Hull & Katz, 2006; Ohler, 2008). Researchers examining educational environments that integrate digital stories report active student participation in problem-solving and evaluation processes (Chung, 2007). Basically, the expectations in mathematics education to develop students' analysis, creation and critical thinking skills support this idea as well (Küçükoğlu, 2019). The main purpose of this study is to explore classroom teachers' opinions regarding use of the digital story method in mathematics teaching in elementary classroom settings.

Method

Research Model

This research, which aimed to investigate classroom teachers' experiences of using digital stories after they practiced the method at their own grade level in their classroom, was conducted with phenomenological research design, one of the qualitative research methods. The phenomenological research design aims to describe participants' experiences to reveal similar meanings underlying the stated phenomenon (Onat Kocabıyık, 2015) and to present their perceptions and experiences about a phenomenon and the meanings attributed to the aforementioned elements (Yıldırım & Şimşek, 2018). For this purpose, the digital stories planned by the researcher and the activities related to these digital stories were implemented by the classroom teachers during mathematics lessons and the classroom teachers were provided with opportunities to experience the mathematics teaching process with digital storytelling in their own classrooms before their opinions were collected.

Participants

The sample of the research consisted of 25 voluntary classroom teachers employed in public and private primary schools. Convenience sampling, one of the purposeful sampling methods, was used in this research. Among the participants, 14 were males and 11 were females, all the teachers graduated from Faculty of Education. In addition, 19 of the classroom teachers were working in schools in the city center, while 6 of them were working in the schools that were located in various villages. In order to ensure confidentiality, pseudonyms were used instead of participant names in the research.

Data Collection Tools

During the data collection process, the digital stories and lesson plans prepared by the researcher for all levels of primary school were distributed to the participating teachers to examine their opinions on the use of digital stories, and then, they were asked to teach their lessons with the digital story suitable for their grade level. Afterwards, the interview questions prepared in line with the expert feedback to obtain teacher opinions on the use of the digital story method in primary school mathematics teaching were asked in the form of one-to-one interviews which were audio recorded with the permission of the teachers. The questions used during the data collection process are as follows:

1- What comes to your mind when you think of digital storytelling?
2- What are the positive aspects of using the digital story method in the mathematics teaching process?
3- What are the negative aspects of using the digital story method in the mathematics teaching process?
4- What problems can be encountered with the use of digital stories in the mathematics teaching process?
5- What are the opinions you would like to add about the use of digital storytelling in mathematics teaching?

Educational Implementation Process

Preparation of the Digital Stories

A digital story and a lesson plan were prepared for each primary school grade level in line with the acquisitions specified for mathematics teaching to examine classroom teachers' experiences in using the digital story in mathematics teaching. The elements of the digital story identified by Robin (2008), Lambert (2010), and Ohler (2013) were examined while preparing the digital stories for the educational implementation process, and the following eight elements were used: point of view, a dramatic question, emotional relationship, the gift of voice, power of the soundtrack, words of the narrator, economy (time and story length) and pacing.

Implementation of the Digital Stories

Figure 1 provides information about the implementation process of digital stories in teaching mathematics. Teaching time was planned as two class periods (40'+40') in the process of preparing the lesson plans. Classroom teachers completed the teaching process 'Addition with Natural Numbers' for the 1st grades and 'Geometric Patterns' for the 2nd grades. Respectively, 3rd and 4th grade teachers completed the teaching process for 'Geometric Objects and Shapes' and 'Data Processing' in two class hours.

The flowchart for the implementation process for using digital stories in mathematics lessons is provided below:

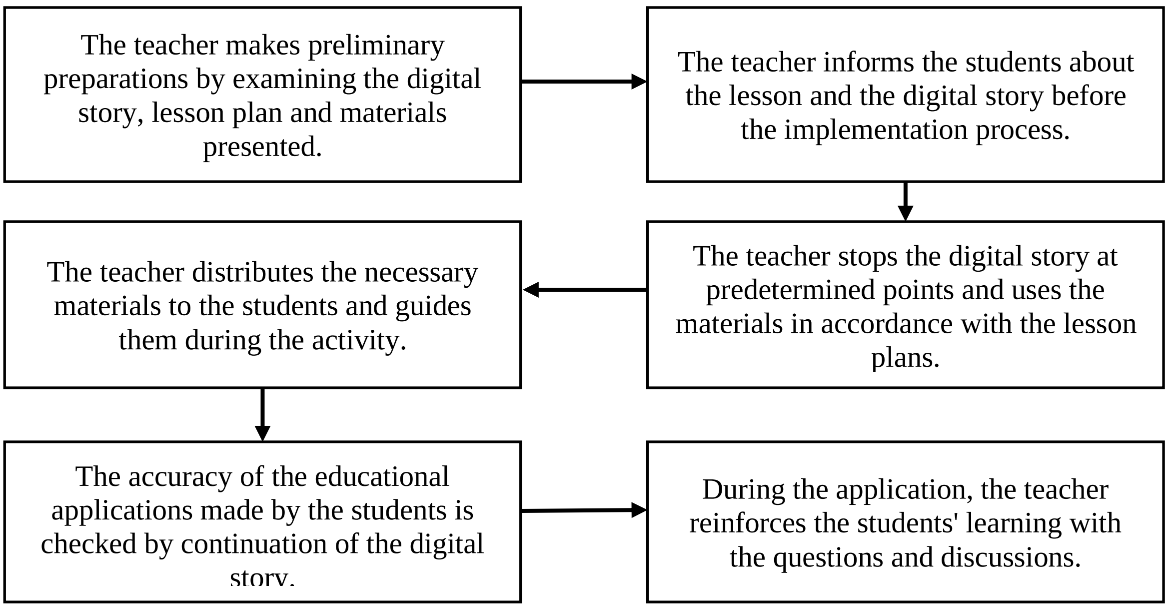

Figure 1 General Flowchart for the Implementation Process

Validity and Reliability

Regarding the validity in qualitative research, Miles and Huberman (1994) suggested taking into account the environment for data collection, using new approaches in the explanation of the obtained data, ensuring the heterogeneity of the sample to allow generalization, and including possible generalizations for the definitions. During the data collection process, it was ensured that the environment was quiet and the distractions were minimized. In addition, the sample was arranged heterogeneously, by taking at least two teachers from each grade level in the primary school, taking into account their employment in schools located in villages or city center.

In order to increase the validity of the study, the literature was examined while preparing the data collection questions and it was decided to investigate the positive and negative aspects of the use of digital story in mathematics teaching and what are the general needs for its use. With this perspective, the data collection questions were revised twice and then sent to 5 scientists specialized in the fields of Turkish language teaching, mathematics teaching in elementary education, mathematics teaching in secondary education, and computer and instructional technology education. Taking into account expert feedback, the 3rd revision was carried out and data collection questions were finalized.

For the implementation process, Lawshe (1975) technique was used to determine the content validity of the digital stories and lesson plans prepared by the researcher for primary school 1st, 2nd, 3rd and 4th grades. The expert opinion form was prepared by using a three point scale in the Lawshe (1975) technique as “the item measures the targeted structure”, “the item is related to the structure but unnecessary” and “the item does not measure the targeted structure” for the evaluation of each digital story and lesson plan. Expert opinion was received for the digital stories and lesson plans in the research from a total of 5 teachers, including 4 classroom teachers and 1 information technology teacher. The Content Validity Rate was calculated as “1” since all experts marked the option “the item measures the targeted structure” for all items.

To increase reliability, the content analysis method created by Yıldırım and Şimşek (2018) and consisting of four stages “Coding the Data”, “Finding the Themes”, “Organizing and Defining the Data Based on the Codes and Themes” and “Interpreting the Findings” was used during data analysis. Based on these stages, the data were coded, categories and themes were created, the data were organized according to these categories and themes, and the findings were interpreted in a clear and understandable manner.

Data Analysis

The data obtained based on the content analysis is first conceptualized, and then organized realistically for the emerging concepts to determine the themes explaining the data.

In data analysis, themes are created based on the concepts, and together with the themes, the facts can be arranged more clearly to make them more comprehensible. The basic process in content analysis is to gather similar data within the framework of certain concepts and themes and to organize and interpret them in a way that the reader can understand (Yıldırım & Şimşek, 2018). Content analysis was conducted in this study to examine classroom teachers' opinions on the use of digital stories in teaching mathematics. Qualitative research data is analyzed in four stages as "Coding the Data", "Finding the Themes", "Organizing and Defining the Data Based on the Codes and Themes" and "Interpreting the Findings".

While coding the data, the researcher examined and divided the obtained data into meaningful sections and tried to determine the conceptual meaning of each section. The sections that formed a meaningful whole together were named and coded by the researcher. Identification of the descriptive codes of the mentioned sections is essential at this stage. For example, in this research, many teachers mentioned that digital stories help in concretizing abstract concepts regarding the positive aspects of using digital stories in teaching mathematics and hence these opinions were gathered under the code of "Opportunity to Concretize Abstract Concepts". Based on the created codes, themes were determined to gather the codes under a general category and explain them in general. In order to establish themes, the codes were combined, examined, and classified according to similar characteristics. In short, themes were created by categorizing the obtained data on the basis of codes. For instance, the codes of "Opportunity to Learn by Having Fun", "Contributing to Student Development" and "Supporting Multiple Intelligence Types" were gathered under the theme of "Positive Aspects for Students".

Following the completion of the thematic coding stage, the data obtained were organized according to the codes and themes. The analysis method developed by Lincoln and Guba (1985) for the coding of data in qualitative studies was used in this research. Accordingly, new codes created during the coding process were added to the code booklet in order to assess whether the generated code booklet was satisfactory for the examined data. The themes in the code booklet were checked repeatedly and changes were made where necessary. The relationships recognized between the themes during the data analysis were transferred to the code booklet and the codes which were originally included but were deemed unnecessary during the analysis process were removed (Lincoln & Guba, 1985).

Results

The data obtained from the classroom teachers' experiences of mathematics teaching with digital stories are examined under the titles of "Positive Aspects of Using Digital Stories in Teaching Mathematics " and "Negative Aspects of Using Digital Stories in Teaching Mathematics " in this section.

Positive Aspects of Using Digital Stories in Teaching Mathematics

Table 1 Themes and Categories Regarding Classroom Teachers' Opinions on the Positive Aspects of Using Digital Storytelling in Teaching Mathematics

Theme	Category	Classroom teachers
Positive aspects for learning	Opportunity to concretize abstract concepts Opportunity to learn by doing Facilitator in transferring to daily life Ensuring retention Attracting attention to the lesson Opportunity to ıncrease achievement	Arda, Arzu, Bilge, Elif, Emin, Furkan, İlker, Sude,
Positive aspects for teachers	Time saving Supplementary resource	Demir, Emin, Alper
Positive aspects for students	Opportunity to learn by having fun Contributing to student development Supporting multiple ıntelligence types	Ozan, Elif, Gamze

Positive Aspects for Learning

The classroom teachers stated that students did not have abstract thinking in general due to their developmental stages so many of the mathematics subjects remained nonconcrete for them. They mentioned that the digital stories provided the opportunity to embody the mentioned abstract subjects by appealing to more than one sense. Arda Teacher stated that digital stories ensured concretization of the subjects with the following words:

> *Since the children are not in the abstract thinking stage, they would like everything to be concrete. They need to see (it) with their own eyes. The materials you prepared were very helpful to us in that regard. For example, in recognizing objects. Watching the animation there, seeing it digitally and following the lesson by touching and feeling it, in a way, reinforced the learning of the children. –* ***Arda***

Arzu Teacher emphasized that digital stories provided the opportunity to concretize the math subjects:

> *To be able to present the visual to the student by concretizing the abstract*

information. Mathematics teaching generally remains abstract, but it is important to concretize it. - ***Arzu***

Classroom teachers stated that teaching mathematics with digital stories allowed the learning process to be integrated into daily life. Among her positive views on the learning process, Bilge Teacher mentioned that the use of digital stories facilitated the transfer to daily life in the following manner:

Nice practice. Because, as I said at the beginning, children develop a fear of mathematics. They also have difficulties in applying mathematics to daily life. I find it really helpful to use the digital story for this. - ***Bilge***

Elif Teacher explained the positive effects of using digital stories in teaching mathematics as follows, emphasizing that mathematics is everywhere in life:

It attracts the attention of children more. It's a different material, a different activity. In other words, it is turned into a story and they realize that mathematics is actually in our lives. They realize that we use mathematics in every aspect of our lives. It is like that for us and for the children as well. – ***Elif***

Classroom teachers noted that the use of digital stories in teaching mathematics provided permanence in learning. Emin teacher explained that the mathematics teaching process carried out with digital stories provided higher retention in learning with the following sentences:

It makes the lesson more fun as the subjects are handled with materials and tools. It makes it more permanent. In the images there were models. For example, in our addition activity, since the models there visually attract students' attention, they also increase retention. In the same way, if we consider the use of the senses, for example, hearing, seeing, etc., when these senses are used together, the permanence increases even more. - ***Emin***

Furkan Teacher talked about his experience of using digital stories in teaching mathematics in his own class and stated that using digital stories increased retention since they appealed to more than one sense.

When students have more visual and auditory videos like these, learning becomes more permanent and it is difficult for students to forget. I think it is extremely useful. Because when we tried to explain to the students the subject we covered, *using both the materials and the digital story, the students really learned more and did it more easily. -* ***Furkan***

Classroom teachers explained that using digital stories in teaching mathematics was beneficial in increasing the students' interest in the lesson, motivating them, and thus keeping the attention high throughout the lesson. Below, you can find the opinion of İlker Teacher that emphasized how the use of digital stories in teaching mathematics helped to draw attention to the lesson based on his observations:

We have observed that it is very useful in attracting attention, drawing interest, in the implementation stage. In other words, it was very useful in attracting student attention to the lesson. As far as I have observed, we can talk about the positive aspects of motivation, increasing interest in the lesson. – ***İlker***

The opinions of Sude Teacher, emphasizing the involvement of the student in the digital story process in mathematics teaching, are provided below:

First of all, it gives visual information to the children. Both visual and auditory, some applications include the child in the activities we do afterwards. In that sense, the child is involved in the activity. Instead of just watching and listening. I think it's much more insightful and remarkable. I also think that using [digital storytelling] in teaching mathematics strengthens and supports learning. – ***Sude***

Positive Aspects for Teachers

During the course of investigating the positive opinions of classroom teachers towards the implementation of digital stories into the mathematics education process, the categories of time-saving and study aid were developed. The above categories were grouped under the theme of Positive Aspects from the Teacher's Perspective. The lassroom teacher Demir pointed out that the usage of digital stories in teaching mathematics helps the teacher to quickly present the subject matter as follows:

It prevents the teacher from becoming more tired, saves time, and speeds up the achievement of the desired achievement. I interpret it this way. ***- Demir***

Classroom teachers mentioned that using digital stories to teach mathematics might serve as motivating teaching material for teachers themselves. The following are the views of teacher Emin, who emphasized that digital stories are useful as a study aid for teachers:

Looking from the teacher's perspective, firstly, it provides a variety of options as *a study aid and the teacher as a supportive learning aid. Compared to presenting the lesson on your own, using the video as a learning aid, motivates students and helps you as a teacher.* – ***Emin***

While teacher Alper acknowledged that digital stories were beneficial as a study aid, he emphasized that they helped him keep the classroom in control:

Honestly, I've never used a digital story before. Then I observed that the students are much better prepared for the class and significantly more engaged. And I observed that digital storytelling offered better classroom management when I was unable to control it. It seems like an aid that I will use from now on. So, digital storytelling has become a teaching material for me as well. I can use it as a supportive element. - ***Alper***

Positive Aspects for Students

Concerning the positive opinions of classroom teachers regarding the use of digital stories in mathematics teaching, the categories of opportunity to learn by having fun, contribution to student development, and support for multiple intelligence types were created. The grouping of the aforementioned categories under the theme of "Positive Aspects from the Student's Perspective" was considered appropriate. According to a classroom teacher, unlike traditional teaching methods, the use of digital stories in mathematics teaching enables students to learn while having fun. Teacher Ozan used the following statements to describe how students were affected by the usage of digital stories in mathematics teaching in terms of learning by having fun:

Its benefits include preventing the child from being bored and making learning more enjoyable via the use of stories. Those are the positive aspects. It's more fun, they do it with a lot of fun, which we observed in class. They do it easily. They didn't have that much fun when we were discussing the subject of the pattern. Because our methods and the methods in the book are fairly traditional, this way makes the process more enjoyable. - ***Ozan***

A classroom school teacher indicated that the use of digital stories in mathematics teaching promotes the psychomotor development of students. The development of the student is fostered by the student's participation in the teaching process using digital story, as mentioned by the teacher Elif with the following words:

It was a unique activity that grabbed the children's attention. Through cutting *and gluing, children have also reinforced their hand muscles. And that was a different and nice thing. In fact, it can be used at any stage. In other words, it may be applied once per week or once every 10 days in a math class. So that, we can incorporate it with other lessons. I believe that is a good and applicable method.* ***- Elif***

As a result of the fact that digital stories differentiate the process of teaching mathematics, they accommodate different types of intelligence, hence reducing individual differences in learning. With the following explanations, teacher Gamze stated that digital stories are intended to appeal to different types of intelligence:

I think it comes with several positive aspects. The story targets both visual memory and auditory intelligence as it is delivered as a video. You know that intelligence types are quite crucial for students at that age. Thus, I think it can be more effective when the subject is explained in a differentiated way. Therefore, I support using digital stories. ***-Gamze***

Negative Aspects of Using Digital Stories in Teaching Mathematics

Table 2 Themes and Categories Regarding Classroom Teachers' Opinions on the Negative Aspects of Using Digital Story in Teaching Mathematics

Theme	Category	Classroom teachers
Negative aspects for students	Turning into a habit Individual differences Technology saturation Readiness	Arda, Sude, Elif, Cem, Alper, Zehra, Demir
Negative aspects regarding the teaching environment	Lack of technological Infrastructure	Ezgi, Oğuz, Didem
Negative aspects for teachers	Time constraints Crowded classrooms	Figen, Ozan, Eylül, Hakan, Ezgi, Zehra

Negative Aspects for Students

Classroom teachers stated that the use of digital stories in teaching mathematics and the continuous use of digital stories in teaching will cause negative results if this method turns into a habit over time. Arda Teacher highlighted the negative aspects of using the digital story continuously in teaching mathematics with the following sentences:

It has to be used in moderation. It may be good for the teacher to use it as an introduction to some subjects in the introduction, as you mentioned, and to do the rest with other methods. However, it is seen that the children constantly need it after a certain point, when the lesson is carried out with it[digital story] or the *subjects are taught with it. It can also cause problems in the future. –* ***Arda***

Similarly, the opinions of Sude Teacher which explained that the continuous use of digital stories in teaching mathematics would easily turn into a habit, considering the technology competencies of today's students are given below:

Let me see, as I said, children are very prone to this[digital technology] and they can solve how to use everything digital in two minutes. However, the harmful aspects of this are, of course, that the child does these in the virtual world. Doing virtual activities, not touching anything in reality. It directs the child more towards the digital. The child does not want to write or draw later. He wants to place the shape there because it is easier. You say, for example, let's draw a square, draw a cylinder. The child does not have the skill to draw cylinders. Does not use pen and notebook correctly. ***- Sude***

Classroom teachers mentioned that having some students with attention problems or with different languages made it difficult for students to adapt to the learning process when digital stories were used in teaching mathematics. With the following statement, Elif Teacher explained that not every child was able to listen to a digital story in the teaching process carried out with digital stories:

I mean, not every child can listen to the story. The disadvantage may not apply to the whole class. when it is digital, Sometimes, children cannot be guided to it, they do not listen much. They can get distracted after a while. Therefore, not every child can adapt. – ***Elif***

In the following sentences, Cem Teacher expressed the problems experienced by the students who used different languages in the mathematics lesson taught with a digital story:

As I said, children did not understand some of the things due to language. The students in our region are very problematic in terms of language. Some of them are Syrian, some come from Urfa, and they speak Arabic all the time at home. Most of the Turkish words are a little troublesome for younger students. So we experienced some problems with the language. – ***Cem***

The opinions of Alper Teacher, who experienced a similar problem caused by students' individual differences in the use of digital stories are given below:

At my school, the digital story may not work for some children because children *may have language problems, because they are of Syrian or Arab origin. Some things are left unfinished because all of them cannot speak Turkish. Things cannot be transferred to other students fully. Another disadvantage is that some children may have conditions such as heavy hearing issues because of ear problems. When it comes to severe hearing conditions, children also cannot hear or perceive what they hear. There are such problems. –* ***Alper***

Classroom teachers stated that the digital story may not attract students' attention while teaching mathematics simply because students generally have easy access to technological tools and equipment and due to being so intertwined with technology in this age we live in. Elif Teacher stated that digital stories do not attract the attention of students addicted to technology with the following words:

Addicted children cannot turn to digital stories either. They can't concentrate, because it's an environment they're used to anyway, so it doesn't seem different to them. For example, it is the case for our students. In other words, doing something digital with them did not attract their attention so far. It becomes very ordinary.

– ***Elif***

In the following sentences, Zehra Teacher explained students' technology saturation and the problems it causes:

Some children have trouble concentrating. We're having a hard time attracting these kids. Now children have had enough of the digital environment. They expect different things from you. It is a little more difficult to influence them– ***Zehra***

Negative Aspects regarding the Teaching Environment

Classroom teachers mentioned that the lack of computers, internet and smart boards can cause problems in using digital stories in teaching mathematics. The opinions of Ezgi Teacher on the lack of technological infrastructure as the first problem to mind about the digital story method are given below:

Here, if there is no problem with the internet network, the video lecture is efficient in terms of teaching children the lesson. So I just thought of standard problems like internet, computers… Other than that, I don't see a problem, frankly. - ***Ezgi***

The explanations of Oğuz Teacher about what kind of problems can be encountered in the use of digital stories in teaching mathematics are given below:

> Since it is carried out in a technological environment, problems with electricity and internet can sometimes be experienced. Infrastructure problems may occur. There may be situations where children have limited access to technology. – ***Oğuz***

Didem Teacher talked about the effects of technological infrastructure problems on digital stories used in teaching with the following sentences:

> *Disadvantages may occur due to technological problems. As a disadvantage, maybe not for digital stories, but in some schools, digital stories may not be used efficiently in cases where there is no smart board or internet cannot be provided, there can be blackouts. –* ***Didem***

Negative Aspects for Teachers

Classroom teachers stated that the use of digital stories in teaching mathematics has negative consequences for teachers due to the slow progress in the process and the one-to-one activities. The opinions of Figen Teacher regarding the time constraints related to the digital story process in teaching are given below:

> *More time is consumed. It's going slower. Time loss may be extreme. I would say it takes too much time. Also, since there are individual differences in children, it may be slower for some to learn. It can cause problems in terms of individual differences. It also makes us to use more time. It is not time efficient for us. –* ***Figen***

Ozan Teacher explained that the topics took a longer time when digital stories were used in teaching mathematics:

> *We may experience a lot of problems with the curriculum due to time. When we process it as a story, it provides permanence for children, but it can cause a loss of time because the topics in the normal curriculum are too long. Of course, it takes a lot of time, at least 1-2 hours, to tell each story, to have students watch it and then to turn it into an activity. –* ***Ozan***

Similarly, Eylül Teacher explained as follows with examples from her own class that the students had a hard time adapting to the process when the digital story was used for the first time in the classroom:

> *The time given to us was very short. For example, in forty minutes, we started the*

*story; especially the column chart and the scoreboard table are done one after another since they are like the parts of a whole, so we had some time problems. We had to continue in the second class hour. It is necessary to plan the time well. When planning such trainings, it is necessary to allocate time not only to animation, but also to the activity within the lesson. The digital story was already short. But you have to close it because the student will watch, collect the data himself, of course, it is a bit of a problem for the child who lags behind – **Eylül***

Classroom teachers expressed their opinions about the problems in maintaining classroom control due to the large number of students while using digital stories in teaching mathematics. For example, Hakan Teacher expressed his concern about the use of digital stories in teaching mathematics in crowded classrooms with the following words: *"It is a difficult method in crowded classrooms. I think children should be accustomed to group work to use this method*." Ezgi Teacher explained that she did not use digital stories in teaching mathematics because her class was crowded and the topics were lengthy:

*It's a bit of a waste of time for us, I think, since our classes are crowded, children can spend more time on examples after video lectures in less crowded classes. But since the class is crowded and there are too many students, I can't use it in math class, frankly. – **Ezgi***

Below, the explanations of Zehra Teacher are given who emphasized that using digital stories in mathematics lessons in crowded classrooms make it difficult for the teacher to control the class:

*Number of students. I think it would be more appropriate and healthier if the activity was done in a group of twenty people. It is a little more problematic in crowded settings. There are issues with time. It takes longer. Control is more difficult. As I said, if we are to take our life as a model, we always try to be practical because we always work in crowded settings. We are trying to save time. We are trying to speed up the activity by checking the children one by one visually by glancing at them haphazardly. **– Zehra***

Conclusions and Discussion

This study aimed to examine classroom teachers' experiences in teaching mathematics with digital stories. For this purpose, teachers' opinions on the positive and negative effects of digital storytelling and mathematics teaching were discussed, and suggestions were given for the implementation process of digital storytelling, taking classroom teachers' opinions into account. According to the research results, teachers often cited the positive effects of using digital stories on the mathematics teaching process. Teachers mentioned that students had difficulty understanding abstract subjects due to their developmental level and that the mathematics teaching process conducted with digital stories enabled them to visualize the subject more easily by narrating the subject with visuals. Kahraman (2013) similarly argued that the use of digital stories in physics lessons helped to embody educational knowledge and supported effective learning. Kocaman Karoğlu (2016) emphasized that digital stories provided the opportunity to concretize abstract concepts and stated that students had the opportunity to experience concrete learning thanks to digital stories. From this point of view, it is recommended to support the preparation of digital stories for use in teaching by taking into account the students' developmental levels with understandable visuals and content that carry examples from daily life and provide concrete experiences.

Classroom teachers stated that the use of digital stories in teaching mathematics allowed students to learn by doing by appealing to more than one sensory organ and by ensuring their active participation in the process. Similarly, Göçen (2014) found that using the digital story in the lesson ensured students' active participation in the process and provided the opportunity to learn by doing; in addition, the presence of elements supporting more than one sensory organ enabled students to realize meaningful learning. Polater (2019) emphasized the importance of conducting values education with digital stories, as digital stories provide an opportunity to learn by doing and facilitate the transfer of learning to daily life. In this respect, the opinions presented in the studies in the literature support the opinions of the teachers who took part in this research since it is cited time and again that using the digital story in teaching activates many sensory organs and increases active participation by ensuring learning by doing. Based on the suggestions of the aforementioned researchers and the findings of this study, it is recommended that digital stories are not only used as a material to present information on the subject, but rather to be supported with activities and materials that will attract students' attention, enable them to learn while having fun, and actively gain concrete experiences in the process.

In this study, teachers mentioned that digital stories facilitated the transfer of the information obtained within the scope of the learning process to daily life, as they carried examples from students' real lives. Kayalı (2019) reported in his research that the digital story method contributed to the development of design-oriented thinking skills in secondary school students by allowing them to produce solutions to the problems they experienced in daily life with. Kahraman (2013) cited in his research that digital stories facilitated learning physics and allowed retention because they contained visual elements and could be associated with daily life. It was found in this study that the teachers believed that the digital stories containing examples from life and enabling students to transfer their knowledge to daily life would enable the students to make sense of the subject more easily, make their learning permanent, and provide them with concrete experiences. Designing digital stories around students' interests and lives will help students to reflect the knowledge they have acquired within the scope of the course to their daily lives.

Dinçer and Yılmaz (2019) reported that using digital storytelling in a mathematics course increased students' mathematics achievement. Similarly, Torun (2016) and Pala (2021) concluded in their research that the teaching process carried out with digital stories increased students' academic achievement. Similarly, in this study, teachers emphasized the importance of integrating technology into the teaching process to keep up with the current era, and mentioned that the use of digital stories in mathematics can increase mathematics achievement. It was identified in the study that the teachers believed that teaching mathematics with digital stories had a positive effect on students' academic achievement which was supported by the findings in the literature. Based on this point of view, it can be argued that planning the teaching process with a digital story will have efficient results in increasing student achievement in the course.

Classroom teachers stated that using digital stories in teaching mathematics would be beneficial in drawing attention to the lesson during the learning process because it would motivate students for active participation, support them with materials, present interesting content, appeal to more than one sensory organ, and include examples from real life. Sarıtepeci (2016) and Özüdoğru (2021) identified that when the social studies course was taught with digital stories, digital stories motivated the students, allowed active and willing participation in the process and attracted their attention. Similarly, Hung et al. (2012) and Yang and Wu (2012) reported that the use of digital stories in Science and English teaching, respectively, positively affects students' motivation towards the class. Balaman (2016b) reported that digital stories enabled students to be active during the teaching process. In line with the findings of this research and the emphasized opinions, it is believed that using digital stories during the teaching process will let students listen to the lesson more carefully since the method will increase their active participation, interest and motivation in the lesson.

Classroom teachers stated that individual differences such as attention deficit, having diverse native languages, hearing problems and the presence of individuals in need of special education in the classroom would cause problems in using digital stories in mathematics teaching. Classroom teachers emphasized that some students may have concentration problems during mathematics teaching conducted with digital stories and that they may get bored when the same method is used all the time. Demirer (2013) found that the implementation of educational processes with the digital story increased the motivation and participation of shy students in the lesson. Considering this opinion and the opinion of the teachers participating in this research, it can be argued that the negative aspects caused by individual differences can also be eliminated with digital stories. Karakoyun (2014) mentioned that negative results may occur based on individual differences in the digital story teaching process if individuals progress at different speeds during the application. Preparing the digital stories by taking these factors into account and planning the activities and materials by considering the students' situations will provide an opportunity for students with individual differences to benefit from the educational process more effectively.

Classroom teachers regarded the lack of technological infrastructure as the disadvantage of teaching mathematics with digital stories. Yürük (2015) reported that although the digital story has more than one positive feature, there is no infrastructure that can disseminate and popularize the digital story as a teaching material. Sarıtepeci (2016) argued that students generally experienced problems with the technological infrastructure in the process of creating digital stories. Teachers in this study mentioned that the absence of tools such as the internet, computer and smart board in schools or the emergence of infrastructure problems such as power cuts during implementation would negatively affect the mathematics teaching process conducted with digital stories. Thus the sufficiency of digital requirements such as smart boards, computers, projections, sound systems, and the internet in classes where teaching will be carried out with digital stories should be regularly checked to minimize the negative situations that may be encountered during teaching.

According to classroom teachers, the use of digital stories in mathematics teaching would lead to a loss of time for teachers by prolonging the teaching process due to the intensity of the curriculum, the active roles of the students in the process and the learning differences. Van Gills (2005) reported that the use of digital stories in teaching has successful results, but the educational process takes more time than traditional approaches. Teachers reported the large number of students in the classrooms, the inability to reproduce the examples, the loss of time and the lack of classroom control as problems that would undermine the efficiency of using digital stories in teaching mathematics. When teachers' opinions in this regard and the primary school mathematics curriculum are examined, it can be argued that the curriculum is rather dense. In addition, classroom teachers also mentioned situations where teaching needed to be repeated from the beginning due to students' individual and learning differences. In this context, to reduce the disruptions in the curriculum, it can be suggested to practice digital storytelling in mathematics teaching in specific subjects to increase student participation rather than implementing the method in every mathematics lesson. In addition, expanding the class hours for the mathematical concepts in the curriculum and providing in-service training to support these changes will help reduce classroom teachers' concerns regarding time limitations and motivate them to prefer student-centered teaching approaches such as digital storytelling.

Recommendations

The classroom teachers emphasized that group work was not suitable for all student levels in the teaching process planned with digital stories. For this reason, it is suggested that attention should be paid to the language characteristics, readiness, class level and individual and learning differences of the student while making decisions about organizing the activities as group work or individual study.

The classroom teachers reported experiencing difficulties in using digital stories in teaching mathematics due to crowded classrooms. In this respect, it is thought that the size and the physical characteristics of the class should be taken into account when creating a digital story.

The classroom teachers thought that teaching with digital stories would make teachers lose time since they believed density of the mathematics curriculum. Therefore, the time required to use alternative teaching methods in the classroom should be taken into account while preparing the next mathematics curriculum to reduce concerns about curriculum density.

The classroom teachers mentioned that the inability to support digital stories with materials in mathematics teaching will negatively affect students' active participation in the process. For this reason, it would be appropriate to create and distribute lesson plans and inexpensive and easy-to-prepare materials related to digital mathematics stories by experts in the Ministry of National Education.

Compliance with Ethical Standards

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Sınıf Öğretmenlerinin Dijital Öykü Kullanımına Yönelik Deneyimlerinin İncelenmesi

Özet:

Bu çalışmada sınıf öğretmenlerinin matematik öğretim sürecinde dijital öykü kullanılmasına yönelik deneyimlerinin incelenmesi amaçlanmış ve bu doğrultuda nitel araştırma yöntemlerinden olgubilim araştırması deseni kullanılmıştır. Veri toplama sürecinde, matematik dersi kapsamında araştırmacı tarafından ilkokulun her kademesi için hazırlanan dijital öyküler ve ders planları katılımcı öğretmenlere dağıtılmıştır. Öğretmenlerden öğretim yaptıkları sınıf seviyesine uygun olan dijital öyküyle birlikte derslerini işlemeleri istenmiştir. Bulgular doğrultusunda öğretmenlerin matematik öğretiminin dijital öyküyle yürütülmesinin soyut kavramları somutlaştırma, akılda kalıcılığı sağlama, dikkati derse çekme, yaşama transferi kolaylaştırmayı sağladığı yönünde olumlu görüş bildirdikleri tespit edilmiştir. Öğretmenlerin matematik öğretiminde dijital öykünün kullanılmasının dezavantajları kapsamındaysa teknoloji kullanımının alışkanlığa dönüşmesi, öğrencilerin bireysel farklılıkları, öğretim ortamındaki teknolojik donanımın yetersiz olması, zaman alması şeklinde olumsuzlukların ortaya çıkabileceğinden bahsettikleri görülmektedir.

Anahtar kelimeler: Dijital öykü, matematik öğretimi, sınıf öğretmeni.

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