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# Opinions of elementary mathematics teacher candidates on the use of digital technologies in mathematics education

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**Highlights**

- Many elementary mathematics teacher candidates do not encounter digital technologies in mathematics lessons before undergraduate courses.
- Undergraduate courses in the elementary mathematics education program affect teacher candidates' use of digital technologies.
- COVID-19 has opened the door to the necessity and use of digital technologies in mathematics education.
- Teacher candidates mostly refer to WEB 2.0 tools among the digital technology tools that can be used in mathematics education.

**Article Info:** Research Article

**Keywords:** *Digital technology, mathematics education, teacher candidates*

**Abstract**

Although it is desired to be integrated into education quickly with the advancement of technology, it takes time to embed such changes in education. Teachers and teacher candidates are expected to have sufficient readiness and technological infrastructure in order to keep up with the targeted and rapid transformations. The study aims to determine the views of elementary mathematics teacher candidates (EMTC) on the use of digital technology (DT) in mathematics education. A case study, one of the qualitative research methods, was used in the research. The data of the study conducted with 83 elementary mathematics teacher candidates were collected within the framework of nine open-ended questions. In line with the analyses carried out, it was concluded that undergraduate courses positively affect the use of digital technologies in mathematics education. It has been stated that the COVID-19 pandemic has opened the door to the use of digital technologies in mathematics education, and opinions on what digital technologies can be used in mathematics education have been put forward. Suggestions were made that teacher candidates should increase the courses on the use of digital technologies in their undergraduate education.

## 1. Introduction

As advances in science and technology affect societies and individuals, these developments have also affected education (Ersoy, 2003). While this progress in modern technologies affects every aspect of our lives, this effect has also been found in education. In this context, digitalization is seen as philosophical and ideological progress in contemporary societies (Karlsson et al., 2022). Therefore, it can be said that every field of education is affected by the technology and digitalization movement in different dimensions and fields. Today, it has become a necessity for technologies in all areas of our lives to take place in education as well as in the lives of individuals. In this context, it is no longer possible for schools to ignore the impact of technology and the change in curricula (Alexiou-Ray et al., 2003). In today's 21st century, it has become inevitable to use technology in the education of individuals who grow up with technology (Öztop & Özerbaş, 2019).

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Terms that are a part of our education life such as online courses, open online learning, touch technology have become an integral part of daily life in an age where approximately 45% of the world's population has internet access (Borba et al., 2016). Considering that the global internet users are 4.95 billion at the beginning of 2022 (Recrodigital, 2022), we can say that more than half of the world's population has access to digital technologies (DT). For young people, DTs have become an integral part of daily life. This is reflected in the statement by Mantilla and Edwards (2019) that one-third of pre-school children in Australia spend 26 hours a week on a tablet or smartphone, and Lai and Hong (2015) conducted a study with 799 undergraduate and 81 graduate students, with one-third of the participants 20 hours a week. It supports the view that they use DTs for business and social purposes for more than an hour. In light of this information, despite the enormous level of access and use of DTs, there are many reports that teachers fail to integrate technology into their lessons (Bozkurt & Cilavdaroğlu, 2011; Ertmer et al., 2012; Ulaş & Ozan, 2010; Zhao et al., 2022). It publishes plans to address this problem and to encourage student-centered learning with technology to increase student achievement in countries. One of these plans is the National Education Technology Plan, published by the US Department of Education in 2010 (U.S. Department of Education, 2010). The British Educational Communications and Technology Agency (BECTA) (2003) produced a report identifying several beneficial aspects of using DTs, such as positive motivational benefits, focus on strategies, supporting a constructivist pedagogy, and promoting higher-order thinking skills and problem-solving strategies. In Türkiye, many projects, especially the FATIH project, have been implemented to increase the use of technology by teachers and students (Çakır & Oktay, 2013). It can be seen as one of these projects in the 2023 education vision, and the necessity of digitalization in the future of education has been mentioned by referring to the use of technology in many places (MoNE, 2018).

It can be said that DT skills have an important contribution to the development of technical and professional skills of individuals, as well as their understanding, adoption, and use of technologies (Matos et al., 2019). When 21st century skills including life and career skills, learning and innovation skills, and information, media & technology skills are examined, it is striking that technology skills have an undeniable multiplicity in lifelong learning (Battelle for Kids, 2019). Today, where technology affects every field, education necessitates the integration of technology into education. In this context, it can be said that the use of technology in mathematics education as well as the use of technology in education is another application area of technology (Öksüz & Ak, 2010). With the inclusion of technology in mathematics classrooms, DTs have become a trend in mathematics education (Borba, 2021).

Although it is desired to be integrated into education quickly with the advancement of technology, the pace of this change in the field of education of DTs has remained constant (Ng, 2015). It is recommended that especially DTs be used in education to develop 21st century skills (Eryılmaz & Uluyol, 2015). In order for teachers and teacher candidates to keep up with the targets and rapid transformations, their readiness and technological infrastructure must be completed. The aim of the research carried out in this context is to determine the views of pre-service elementary mathematics teachers on the use of DTs in mathematics education.

21st century students, in other words, "millennials" are intertwined with DTs that store and transmit digital information such as computers, tablets, mobile phones, smart devices, internet, cameras, and web 2.0 tools. Students of our age continue their education by being exposed to very different DTs that did not exist in the past (Brown & Czerniewicz, 2010). In this context, the knowledge and thoughts of teachers and teacher candidates about the use and integration of DTs in mathematics education can enable students to construct knowledge from different perspectives in mathematics education, thus enabling meaningful learning to take place. In addition, it is seen that there are not enough studies examining the opinions of teachers and teacher candidates about DTs in mathematics education. Therefore, it is thought that teacher candidates' views on DTs in mathematics education will make a remarkable contribution to the training of 21st century individuals and to preparing students for the future by making use of DTs. In this context, in this study, mathematics teacher candidates' use of DTs in mathematics education before and after their undergraduate education; the effect and contribution of DTs in mathematics education; the effects of the COVID-19 outbreak on the thoughts, interest, and motivation of the course on the use of DTs in mathematics education; determining which DTs are used in mathematics education; their thoughts about the purpose of use were investigated. It is important to provide a framework for the use of DTs in mathematics education by determining the use of DTs by elementary mathematics teacher candidates (EMTC), the effect of DTs on mathematics education, the effect of the COVID-19 process on the use of DTs in terms of guiding future research and contributing to the literature. In line with the opinions of EMTCs, the effect of undergraduate education on the use of DTs, DTs that can be used in mathematics education, revealing which subjects or concepts in mathematics education can use DTs will be beneficial in terms of guiding teachers and teacher candidates who will use DTs in mathematics education.

In this study, answers to the following research questions were sought within the framework of the aim of determining the views of EMTCs on the use of DTs:

1. What is the effect of elementary mathematics teaching undergraduate program on the use of digital technologies in mathematics education of teacher candidates?

2. Does the COVID-19 pandemic have an impact on the use of digital technologies in mathematics education?

3. What are the opinions of elementary mathematics teacher candidates on the use of digital technologies in mathematics education?

## 2. Literature

There are studies on technology integration in mathematics education. Engelbrecht et al. (2020) studied how the internet affects the mathematics classroom and mathematics teaching are encountered. In the study, it was emphasized that the use of DTs creates new ways of thinking in environments where mathematics is done and thought and supports the professional development of teachers. Clark-Wilson et al. (2020), on the other hand, emphasized the use of DTs in the secondary school stage and made explanations on research areas on teaching technology and mathematics. Brown (2017), on the other hand, examined teachers' perspectives on changes in mathematics education within the framework of the practices carried out in a technology research project. As a result of the study, it was stated that a teacher's participation in technology in mathematics education program may cause a change in the perception of technology use. Loong & Herbert (2018) conducted studies on the use of DTs in mathematics lessons by primary school teachers. It has been stated that teachers' technological pedagogical content knowledge is affected by their previous learning experiences related to technology. Das (2021) tried to analyse the role and effectiveness of e-learning and technology integration in the development of mathematics education. As a result of the study, most of the participants stated that they were comfortable in mathematics lessons where technology is used, mathematics education over the internet is difficult, and that COVID-19 is not a problem for mathematics education, while most teachers emphasized that they do not use any software for mathematics teaching. In addition, the study emphasized that there has been a significant change in perceptions in mathematics education during the COVID-19 pandemic period and technology-supported mathematics education has become even more important.

Tatar et al. (2013) analysed the scientific studies published in Türkiye between 2000 and 2011 on technology supported mathematics education within the framework of various variables. It was emphasized that the use of mathematics software in the studies was not sufficient, studies were generally conducted with undergraduate students, and the questionnaire was preferred more than other data collection tools. Similarly, Öztop and Özerbaş (2019) examined DTs supported theses in the field of classroom education. In the research, it was stated that the most DTs supported theses were carried out in 2015. Besides, it was stated in the studies that most DTs was supported by the web, quantitative methods were preferred more, and achievement-performance tests were used more frequently. Another important and effective point of using DTs in mathematics education is teachers' interest, relevance, motivation, and attitudes towards technology. Because the attitudes, motivations, opinions, and thoughts of teachers and teacher candidates towards digital technologies affect the use of technology in education (Günbaş, 2022). In other words, teachers' choices have a critical role in the successful implementation of DTs (Thomas et al., 2017). In parallel with this result, to what extent teachers use technology in lessons, students' use of technology in lessons is shaped within the framework of teachers' attitudes (Hew & Brush, 2007). There are also studies in this direction in the literature.

Bozkurt (2022) examined the views and awareness of secondary school mathematics teachers towards technology. The institutional framework of Valsiner's field theory study was carried out with 22 secondary school mathematics teachers. It has been observed that teachers cannot support students by using technology in a stagnant way, where their use of technology is limited in free movement areas, unlike the paper-and-pencil environment. After the trainings, it has been revealed that the teachers' free movement areas have expanded, and they have knowledge about many technological applications and software.

Another study carried out with mathematics teachers was put forward by İnce-Muslu and Erduran (2020). İnce-Muslu and Erduran (2020) aimed to determine how secondary school mathematics teachers integrate technology into their classrooms and to find out the technology integration process in mathematics education. In the research conducted within the framework of the case study method, it was emphasized that the participant teacher was able to integrate technology in terms of enriching and validating the narrative but had difficulties in using applications such as Kahoot and GeoGebra. Biagas et al. (2021), on the other hand, conducted investigations on how seventh and eighth-grade mathematics teachers use their microcomputers pedagogically. It has been concluded that teachers' use of technology enables students to better understand mathematical concepts and to approach situations from different perspectives. In addition, it was stated that teachers noticed the transformative effect of DTs on the use of DTs in the structuring of mathematical concepts and digital skills together between teachers and students. Bozkurt and Cilavdaroğlu (2011) tried to determine the perceptions of mathematics and classroom teachers about the purposes of using technology and the subjects they consider while integrating technology into their lessons. A survey model was used in the study conducted with 132 mathematics and classroom teachers. In the study, it was concluded that teachers almost never use algebra and geometry software. It has been stated that teachers have little awareness of the purpose and situations of using technology before and during the lesson.

## 3. Methodology

### *3.1. Research Model/Design*

In the study, a case study design, one of the qualitative research methods, was used to give detailed and elaborated information about the EMTCs' thoughts on the use of DTs in mathematics education, how they use DTs, why and for what purpose DTs are used in mathematics education. A case study is a type of qualitative research that focuses on providing detailed explanations and in-depth analysis of one or more situations (Creswell & Poth 2016; Johnson & Christensen, 2019). According to Yin (2018), case studies are a method in which the questions of why and how are answered by examining the practice, a training, an event, an activity, and the situations of one or more participants in detail. A case study provides the opportunity to examine the researched subject in depth and to explain the cause-effect relationship by examining the relationships between the data (Çepni, 2007). In this context, based on the views of teacher candidates on DTs, in-depth studies were conducted on the use of DTs in mathematics education, their intended use, and the effect of the COVID-19 pandemic on DTs in mathematics education. By examining the relationships between the findings, a case study approach was adopted in order to explain the cause-and-effect relationship based on the findings.

### *3.2. Study Group*

In the determination of the study group of the research, the criterion sampling method, one of the purposeful sampling methods, was preferred. Purposeful sampling methods allow for in-depth analysis of information-rich situations (Yıldırım & Şimşek, 2000). The purposeful sampling method, it is aimed to understand the events or phenomena within the framework of selected situations, and to discover and explain the interaction and relationships between them (Büyüköztürk et al., 2014). The reason why the purposeful sampling method is preferred is that it focuses on in-depth understanding and allows reaching people rich in information (Patton, 2014). Criterion sampling requires working with people, events, and objects that have the criteria determined for the problem situation (Büyüköztürk et al., 2014).

Since the aim of the study was to examine the views of EMTCs on DTs, taking technology-oriented courses in undergraduate education was determined as a criterion. In line with the determined criteria, the study group of the research consists of 83 EMTCs studying in the second, third, and fourth grades of the elementary mathematics teaching department in the spring semester of 2021-2022 at a state university in the Marmara region. EMTCs studying at the university where this study was carried out in Türkiye take at least 66 undergraduate courses, including general culture, teaching profession knowledge, and field courses for mathematics, with a total of 240 ECTS (European Credit Transfer System) during their undergraduate education. In some undergraduate courses, teacher candidates are also given training on instructional technologies and DTs. The reason why EMTCs who are studying in the first year are not included in the study group is that they do not meet the criteria for taking technology courses. First-year students were not included in the study group, since technology-oriented courses such as instructional technologies, algorithms, and programming, which are compulsory in the elementary education mathematics teaching program, are started to be given from the second-grade level. Demographic information for the study group is presented in table 1:

**Table 1.**

Demographics of the study group

| Grade | Male | % | Female | % | Grand Total |
|---|---|---|---|---|---|
| 2nd Grade | 12 | 46.15 | 14 | 53.85 | 26 |
| 3rd Grade | 8 | 26.67 | 22 | 73.33 | 30 |
| 4th Grade | 7 | 25.93 | 20 | 74.07 | 27 |
| Total | 27 | 32.53 | 56 | 67.47 | 83 |

When Table 1 is examined, 83 teacher candidates, 26 (31.33%) from the second grade, 30 (36.14%) from the third grade, and 27 (32.53%) from the fourth grade, participated in the research. 27 (32.53%) of the participants were male and 56 (67.47%) were female. 46.15% of the second-year participants were male (n=12) and 53.85% were female (n=14). At the third-grade level, 8 males (26.67%) and 22 females (73.33%) participated in the study. Of the fourth-grade participants, 25.93% were male (n=7) and 74.07% were female (n=27).

### *3.3. Data Collecting Tools*

The data of the study were obtained within the framework of standardized open-ended interviews. In the standardized open-ended interview, the sequence and exact expressions of the questions are determined beforehand, and open-ended questions are asked to all participants in the same order and the same basic style (Patton, 2014). In the research, the opinions of the participants on digital technologies were obtained by using the open-ended questions given in Appendix. While determining the questions for the standardized open-ended interview, first of all, a literature review on DTs was carried out, question styles were examined, and draft open-ended questions were created. For the draft questions, first, three pre-service teachers who were not included in the research group were asked to explain what they understood about the questions and to indicate if there were any questions they could not understand. Afterward, the final version of the data collection tool consisting of nine open-ended questions was obtained by taking the expert opinion (1 Prof. Dr., 1 Assistant Prof., and 1 Dr.) for open-ended questions.

Considering the COVID-19 pandemic process, open-ended questions were transferred to the online environment via Google forms, and open-ended questions were directed to the participants in the online environment since face-to-face opinions could create problems during the pandemic period. Before getting answers to open-ended questions from the participants, teacher candidates were informed about the research process, and it was emphasized that participation in the research was voluntary and their consent was obtained for participating in the research according to their wishes (Cohen et al., 2007).

### *3.4. Data Analysis*

In the analysis of the research data, the frequency distribution method, which is one of the descriptive statistical methods, and the content analysis method, one of the qualitative data analysis methods, were preferred. Content analysis, which is one of the analysis methods frequently used in social sciences, can be defined as a systematic technique in which some words in a text are summarized with smaller content categories within the framework of coding based on certain rules (Büyüköztürk et. al., 2014). Content analysis refers to an effort to reduce and make sense of qualitative data that requires searching for text, counting renewed words or themes (Patton, 2014). The main purpose of content analysis is to interpret the obtained data in a language that the reader can understand by bringing together similar concepts and expressions by explaining the relationships that can enable them to be understood (Yıldırım & Şimşek, 2000).

In the content analysis, primarily the data obtained from the participants were transferred to an excel file. The views of each teacher candidate were protected by expressing P1, P2, P3… in order to keep the identity of the people expressing their opinions confidential (Cohen et al., 2007). In line with the opinions of the teacher candidates, the codes for the topics related to each question and the themes representing the codes were created. In order to make sense of the created themes and codes, to ensure the intelligibility of the data, and to present them in a framework that the reader can understand, the figures including the codes and themes were created and presented in fig. 1, 2, 3… in the findings section. An online concept networking site was used in the presentation of the figures. While the codes were created for the participant opinions transferred to the Excel file and the themes were determined, the stages of the thematic analysis were adopted by Braun and Clarke (2006). These stages are presented in table 2:

**Table 2.**

Data analysis process

| Phase | Description |
|---|---|
| 1. Familiarization with the data | Transcribing data to excel document, reading, and rereading the material, and annotating general ideas. |
| 2. Generating initial codes | Identifying codes that will systematically express the most relevant and relevant aspects of the data across the entire data set, coding the data, and assembling the relevant data for each code |
| 3. Search for themes | Identifying potential themes that can represent them by compiling the codes and collecting all data related to each potential theme |
| 4. Reviewing themes | Checking the determined codes (stage 1) and the functionality of the themes created within the framework of the codes (2nd stage) |
| 5. Defining and naming of themes | Analysis to refine the specifics of each theme and define the themes whether they are expressed in a language that the reader can understand. |
| 6. Preparation of the report | Selecting and presenting the text fragments obtained from the interviews in order to present the most striking and powerful examples together with the frequencies and |

| | |
|---|---|
| | percentages for the determined codes and themes. Creating figures that can represent the determined themes and codes in order to provide a more comprehensive and understandable framework for the researched subjects. |

Note: Table 2 was adapted from the "phase of thematic analysis" by Braun and Clarke (2006), p. 87.

### *3.5. Validity and Reliability*

In order to provide the validity and reliability criterion of the research; (i) data collection and analysis processes were explained in detail, (ii) frequency tables and participants' views on the codes were presented with one-to-one quotations within the framework of the codes and themes created, and (iii) reliability analysis was carried out for the codings, which were carried out with the help of an independent coder other than the researchers. The formula (reliability= number of agreements/(total number of agreements+disagreements) determined by Miles and Huberman (1994, p.64) was used to calculate the reliability among the coders. Within the framework of the analysis for the consistency between the encoders, the agreement coefficient was calculated as .87 and this value was found to be an acceptable value. In the codes where no agreement was reached, the coders came together and put forward a consensus and common codes were created.

## 4. Findings

### *4.1. Findings related to the first research problem: The effect of undergraduate education*

The first research problem of the study is about the effect of undergraduate courses in the elementary education mathematics teaching program on the use of DTs by EMTCs. In this context, the first four open-ended questions about the data collection tool in Appendix were asked to the EMTCs who participated in the research. Findings for each open-ended question within the framework of the answers obtained from the EMTCs are presented below.

1. Did you use DTs in mathematics education before your undergraduate education? If so, for what purpose did you use it?

The results regarding the use of DTs in mathematics education by EMTCs before undergraduate education are presented in table 3:

**Table 3.**

Findings on EMTCs' use of DTs in mathematics education before undergraduate education

| DT use before undergraduate education | Yes | % | No | % | Total |
|---|---|---|---|---|---|
| 2nd Grade | 12 | 46.2 | 14 | 53.8 | 26 |
| 3rd Grade | 9 | 30.0 | 21 | 70.0 | 30 |
| 4th Grade | 13 | 48.1 | 14 | 51.9 | 27 |
| Total | 34 | 41.0 | 49 | 59.0 | 83 |

When Table 3 is examined, more than half (59%) of the EMTCs participating in the study revealed that DTs were not used in the lessons before their undergraduate education. This ratio stands out as a remarkable ratio. The analysis of the answers of those who answered yes for what purpose they encountered DTs in mathematics education is presented in figure 1 and table 4:

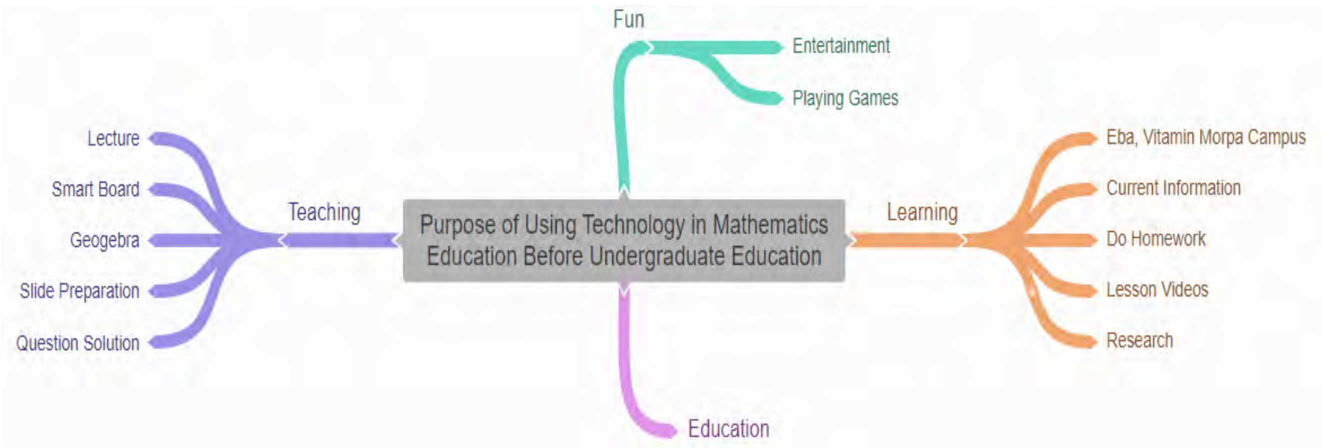


**Fig. 1.** Purpose of using DTs in mathematics education before undergraduate education

**Table 4.**

Finding on the purpose of using DTs in mathematics education before undergraduate education

| Theme | Code | 2nd Grade | 3rd Grade | 4th Grade | Grand Total | % |
|---|---|---|---|---|---|---|
| Education | Education | 1 | | | 1 | 2.56 |
| Teaching | Lecture | 3 | 1 | 6 | 10 | 25.64 |
| | Smartboard | 1 | | | 1 | 2.56 |
| | GeoGebra | | | 1 | 1 | 2.56 |
| | Slide presentation | 1 | | | 1 | 2.56 |
| | Question solution | 1 | | | 1 | 2.56 |
| | Total | 6 | 1 | 7 | 14 | 35.90 |
| Learning | Do homework | | 3 | 2 | 5 | 12.82 |
| | Lesson videos | 2 | 2 | 1 | 5 | 12.82 |
| | Current information | | 1 | 2 | 3 | 7.69 |
| | Learning | 2 | | | 2 | 5.13 |
| | Research | | 1 | | 1 | 2.56 |
| | EBA, Vitamin, Morpa Campus | | | 1 | 1 | 2.56 |
| | Total | 4 | 7 | 6 | 17 | 43.59 |
| Fun | Entertainment | 2 | 1 | 3 | 6 | 15.38 |
| | Playing games | | 1 | | 1 | 2.56 |
| | Total | 2 | 2 | 3 | 7 | 17.95 |
| | Grand Total | 13 | 10 | 16 | 39 | 100 |

According to table 4, participants expressed more opinions about the use of DTs during "lecturing" (n=10, 25.64%) in mathematics education before their undergraduate education. Afterward, DTs are mostly used for "entertainment" (n=6, 15.38%), then "doing homework" and "watching lecture videos" (n=5, 12.82%). When the most mentioned theme in terms of this category is examined, it is seen that it is related to learning (n=17, 43.59%). Some participant views on the codes created within the framework of this category are presented below:

P22: *"Digital technologies were used for lectures in the lessons."* (Lecture)

P47: *"In my high school and primary school life, digital technologies were mostly used for entertainment purposes."* (Entertainment)

P32: *"I usually use it for homework."* (Do homework)

P39: *"Before my undergraduate education, I was using it to listen to the lecture videos of the subjects."* (Lesson videos)

2. Do you intend to use DTs in mathematics education after your undergraduate education? Why?

The findings regarding the tendency of EMTCs to use DTs in mathematics education after undergraduate education are given in table 5:

**Table 5.**

Trends in the DT use in mathematics education after undergraduate education

| DT use after undergraduate education | Yes | % | No | % | Total |
|---|---|---|---|---|---|
| 2nd Grade | 23 | 88.5 | 3 | 11.5 | 26 |
| 3rd Grade | 29 | 96.7 | 1 | 3.3 | 30 |
| 4th Grade | 27 | 100.0 | | 0.0 | 27 |
| Total | 79 | 95.2 | 4 | 4.8 | 83 |

95% (n=79) of EMTCs who participated in the research, almost all of them, stated that they will use DTs in mathematics education after their undergraduate education. It is striking that as the grade level increases, negative thoughts towards the use of DTs in mathematics education decrease. The tendency of all fourth-grade teacher candidates to use DTs after their undergraduate education is a remarkable finding. The results obtained within the framework of the views on the reasons for using DTs in mathematics education after undergraduate education are presented in figure 2 and table 6:

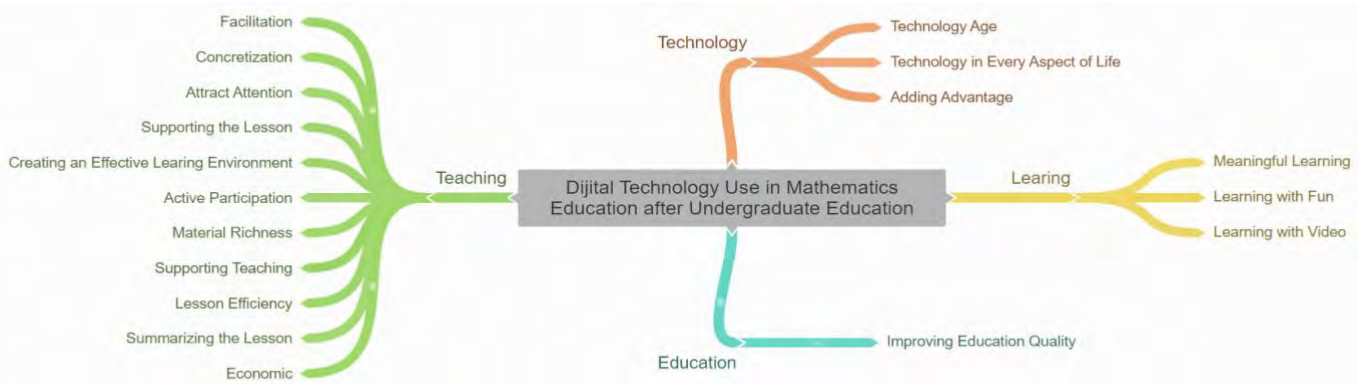


**Fig. 2.** Reasons for DT use in mathematics education after undergraduate education

**Table 6.**

Findings on the reasons for DT use in mathematics education after undergraduate education

| Theme | Code | 2nd Grade | 3rd Grade | 4th Grade | Grand Total | % |
|---|---|---|---|---|---|---|
| Education | Improving Education Quality | | | 1 | 1 | 1.05 |
| Teaching | Facilitation | 4 | 2 | 7 | 13 | 13.68 |
| | Concretization | 2 | 7 | 3 | 12 | 12.63 |
| | Attract attention | 5 | 4 | 3 | 12 | 12.63 |
| | Supporting the lesson | 5 | 3 | 3 | 11 | 11.58 |
| | Creating an effective learning environment | | 6 | 1 | 7 | 7.37 |
| | Active participation | 4 | 1 | 1 | 6 | 6.32 |
| | Material richness | | 2 | | 2 | 2.11 |
| | Supporting teaching | 1 | | | 1 | 1.05 |
| | Lesson efficiency | 1 | | | 1 | 1.05 |
| | Summarizing the lesson | 1 | | | 1 | 1.05 |
| | Economic | | 1 | | 1 | 1.05 |
| | Total | 23 | 26 | 18 | 67 | 70.53 |
| Learning | Meaningful learning | 2 | 5 | 4 | 11 | 11.58 |
| | Learning with fun | | 4 | 1 | 5 | 5.26 |
| | Learning with video | 1 | 1 | | 2 | 2.11 |
| | Total | 3 | 10 | 5 | 18 | 18.95 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Technology | Technology age | 1 | 1 | 4 | 6 | 6.32 |
| | Technology in every aspect of life | 2 | | | 2 | 2.11 |
| | Adding advantage | | 1 | | 1 | 1.05 |
| | Total | 3 | 2 | 4 | 9 | 9.47 |
| Grand Total | | 30 | 38 | 27 | 95 | 100 |

The most frequently cited reason for EMTCs for DT use in mathematics education after their undergraduate education was “Facilitation” (n=13, 13,68%). When we look at the other reasons for DT use, it is seen that "Concretization" and "Attract attention" are expressed more (n = 12, 12.63%), followed by "Meaningful learning" and "Supporting the lesson" (n = 11, 11.58%). Most opinions on the reasons for DT use were put forward in the theme of teaching. In this context, some of the opinions of EMTCs regarding the codes are presented below:

P46: “*We will be teachers and it gives us great convenience while teaching. I plan to use it in my teaching life.*” (Facilitation)

P25: “*I intend to use it to show my students in 3D and to help them understand abstract concepts in a concrete way.”* (Concretization)

P53: “*I think that digital technology web2.0 tools will be useful and interesting in teaching some subjects.”* (Attract attention)

P77: “*…. Because I think that digital technologies are very beneficial for mathematics education by supporting the course.”* (Supporting the lesson)

P39: “*It is important to use technology to revitalize the classroom environment, to make learning permanent and to provide meaningful learning*.” (Meaningful learning)

3. Do you think that your undergraduate lessons have an impact on the use of DTs in mathematics education? Why?

The views of EMTCs on whether the lessons in the elementary mathematics teaching program affect the use of DTs are given in table 7:

**Table 7.**

Findings on the effect of undergraduate courses on the use of DTs

| The effect of undergraduate lessons on the use of DTs | Yes | % | No | % | Total |
|---|---|---|---|---|---|
| 2nd Grade | 17 | 65.4 | 9 | 34.6 | 26 |
| 3rd Grade | 29 | 96.7 | 1 | 3.3 | 30 |
| 4th Grade | 25 | 92.6 | 2 | 7.4 | 27 |
| Total | 71 | 85.5 | 12 | 14.5 | 83 |

Most of the EMTCs emphasized that undergraduate lessons affect the use of DTs (n=71, 85.5%). When we examined the reasons of EMTCs who gave negative opinions, they presented reasons such as the fact that the courses did not make any difference in terms of DTs (n=3), they were not useful (n=1), lack of equipment (n=1), not interesting (n=1). The findings of the content analysis conducted on how undergraduate courses affect teacher candidates' use of digital technology are presented below:


**Fig. 3.** Reasons for undergraduate lessons to affect the use of DTs

**Table 8.**

Findings on the reasons why undergraduate courses affect the use of DTs

| Theme | Code | 2nd Grade | 3rd Grade | 4th Grade | Total | % |
|---|---|---|---|---|---|---|
| Content | Contribution to content education | | | 1 | 1 | 1.41 |
| | Research | 1 | | | 1 | 1.41 |
| | Total | 1 | | 1 | 2 | 2.82 |
| Pedagogy | Effective teaching | 1 | 6 | 4 | 11 | 15.49 |
| | Gaining a different perspective | 3 | 2 | 2 | 7 | 9.86 |
| | Engaging teaching | | 3 | 1 | 4 | 5.63 |
| | Concretization | | 1 | 2 | 3 | 4.23 |
| | Professional use | | 1 | | 1 | 1.41 |
| | Meaningful learning | | 1 | | 1 | 1.41 |
| | Quality education | | 1 | | 1 | 1.41 |
| | Saving time | 1 | | | 1 | 1.41 |
| | Instructional diversity | | 1 | | 1 | 1.41 |
| | Total | 5 | 16 | 9 | 30 | 42.25 |
| Technology | Using technology | 2 | 7 | 6 | 15 | 21.13 |
| | Understanding the importance of technology | 4 | 1 | 1 | 6 | 8.45 |
| | Self-development | | 1 | 4 | 5 | 7.04 |
| | Software usage | | 1 | | 1 | 1.41 |
| | Total | 6 | 10 | 11 | 27 | 38.03 |
| | No idea | 5 | 3 | 4 | 12 | 16.90 |
| | Grand Total | 17 | 29 | 25 | 71 | 100 |

When Table 8 is examined, EMTCs' various opinions such as "undergraduate courses will affect their using technology (n=15, 21.13%), they will provide effective teaching with DTs (n=11, 15.49%), they will gain different perspectives (n=7, 9.86%)" have been put forward those undergraduate lessons contribute to the use of DTs. Pre-service teachers think that the field that undergraduate lessons will contribute the most within the framework of DTs is the field of pedagogy, and then they will contribute to the field of technology. Below are some opinions on the codes determined in line with this category:

P66: "*I think I learned how to use which programs*" (Using technology)

P31: "*I think that subjects and concepts can be taught more easily and effectively*" (Effective teaching)

P35: "*Using different applications gives different perspectives*" (Gaining a different perspective)

4. Which of your undergraduate courses have contributed to the use of digital technology in mathematics education? Explain in what context this contribution is made.

The table of undergraduate courses that contribute to the use of DTs in mathematics education in line with the opinions of EMTCs is presented in table 9:

**Table 9.**

Findings on undergraduate lessons that contribute to the use of DTs in mathematics education

| Theme | Lessons | 2nd Grade | 3rd Grade | 4th Grade | Total | % |
|---|---|---|---|---|---|---|
| Compulsory Lessons | Algorithm and programming | 13 | 5 | 11 | 29 | 19.86 |
| | Geometry and measurement teaching | 1 | 14 | 9 | 24 | 16.44 |
| | Information technologies | 4 | 1 | 4 | 9 | 6.16 |
| | Algebra teaching | | 8 | 1 | 9 | 6.16 |
| | Teaching numbers | | 3 | 3 | 6 | 4.11 |
| | Instructional technologies | 1 | | 3 | 4 | 2.74 |
| | Analysis | 2 | | | 2 | 1.37 |
| | Association in mathematics teaching | | 2 | | 2 | 1.37 |
| | Possibility | 1 | 1 | | 2 | 1.37 |
| | Linear algebra | 1 | | | 1 | 0.68 |
| | Mathematics learning and teaching approaches | 1 | | | 1 | 0.68 |
| | Problem-solving | | | 1 | 1 | 0.68 |
| Elective Lessons | Material design in mathematics teaching | 1 | 14 | 11 | 26 | 17.81 |
| | Computer-aided mathematics teaching | 2 | 5 | 5 | 12 | 8.22 |
| | Internet applications in science | 4 | 1 | | 5 | 3.42 |
| | Self-regulation in mathematics education | 1 | | | 1 | 0.68 |
| | Did not contribute | 9 | 1 | 2 | 12 | 8.22 |
| | Total | 41 | 55 | 50 | 146 | 100 |

When Table 9 is examined, it has been concluded that the most mentioned course among the compulsory lessons that contribute to the use of DTs within the framework of the opinions of EMTCs is “Algorithm and programming” (n=29, 19,86%), and “Geometry and measurement teaching” (n=24, 16.44%). Among the elective lessons, the most frequently mentioned lessons by teacher candidates are “Material design in mathematics teaching” (n=26, 17.81%), followed by “Computer aided mathematics teaching” (n=12, 8.22%). Findings regarding the extent to which undergraduate courses contribute to the use of DTs are given in Figure 4 and Table 10:

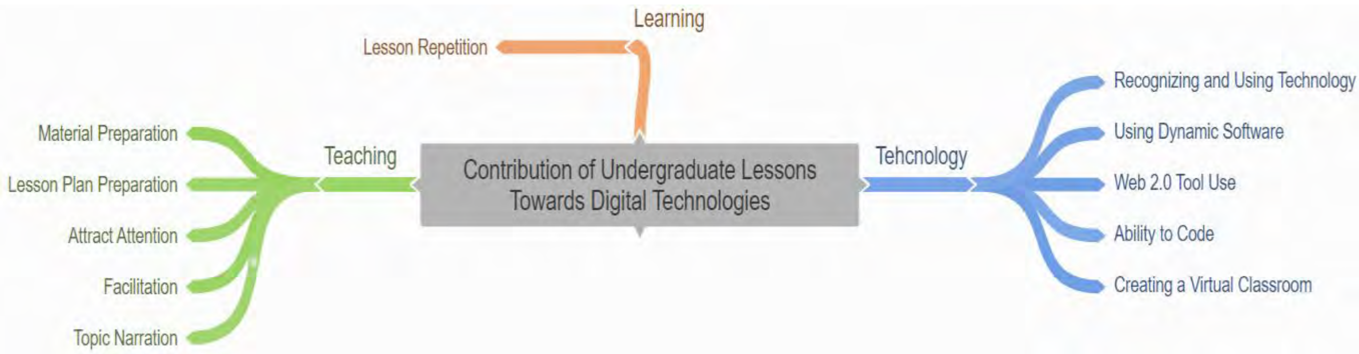


**Fig. 4.** Contribution of undergraduate lessons to the use of digital technology

**Table 10.**

Findings on how undergraduate courses contribute to the use of DTs in mathematics education

| Theme | Code | 2nd Grade | 3rd Grade | 4th Grade | Total | % |
|---|---|---|---|---|---|---|
| Teaching | Material preparation | 4 | 12 | | 16 | 20 |
| | Lesson plan preparation | | 4 | 3 | 7 | 8.75 |
| | Attract attention | 1 | | 2 | 3 | 3.75 |
| | Facilitation | | | 2 | 2 | 2.5 |
| | Topic narration | | 1 | | 1 | 1.25 |
| Learning | Lesson repetition | 3 | | | 3 | 3.75 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Technology | Recognizing and using technology | 5 | 13 | 9 | 27 | 33.75 |
| | Using dynamic software | | 7 | 4 | 11 | 13.75 |
| | Web 2.0 tool use | | 3 | 3 | 6 | 7.5 |
| | Ability to code | | | 3 | 3 | 3.75 |
| | Creating a virtual classroom | 1 | | | 1 | 1.25 |
| | Total | 14 | 40 | 26 | 80 | 100 |

Within the framework of the opinions of EMTCs who participated in the research, the most mentioned concept within the framework of the contribution of undergraduate lessons to the use of DTs was "Recognizing and using technology" (n=27, 33.75%), followed by "material preparation" (n=16, 20%) and "using dynamic software" (n=11, 13.75%).

*4.2. Findings related to the second research problem: The impact of COVID-19*

The second problem of the research is related to the impact of the COVID-19 epidemic on the use of DTs in mathematics education. In this context, EMTCs were asked whether the COVID-19 epidemic affected the use of DTs in mathematics education, whether the distance education lessons held due to COVID-19 affected the interest and motivation in the lessons, and their views on DTs used in distance education mathematics lessons. In this context, the opinions of EMTCs are presented below within the framework of the questions.

5. Has the COVID-19 pandemic affected your thoughts on the use of DTs in mathematics education? What are your grounds?

EMTCs' views on whether the COVID-19 pandemic has affected the use of DTs in mathematics education are presented in Table 11:

**Table 11.**

Findings on the impact of the COVID-19 pandemic on digital technology use

| Impact of the COVID 19 pandemic on digital technology use | Yes | % | No | % | Total |
|---|---|---|---|---|---|
| 2nd Grade | 20 | 76.9 | 6 | 23.1 | 26 |
| 3rd Grade | 29 | 96.7 | 1 | 3.3 | 30 |
| 4th Grade | 26 | 96.3 | 1 | 3.7 | 27 |
| Total | 75 | 90.4 | 8 | 9.6 | 83 |

90.4% (n=75) of EMTCs participating in the research think that the COVID-19 pandemic has affected the use of DTs in mathematics education. When we examine those who think that it does not affect them, it is seen in Table 11 that 75% (n=6) of those who answered no are second-grade teacher candidates.

The opinions of EMTCs on how the COVID-19 pandemic affects the use of DTs in mathematics education are presented below:

**Table 12.**

Findings on how the COVID-19 pandemic affects the use of DTs in mathematics education

| Theme | Code | 2nd Grade | 3rd Grade | 4th Grade | Total | % |
|---|---|---|---|---|---|---|
| Positive | Seeing the necessity of technology | 2 | 13 | 13 | 28 | 32.56 |
| | Extending the use of technology | 5 | 2 | 1 | 8 | 9.30 |
| | Recognizing the lack of technology | | 3 | 5 | 8 | 9.30 |
| | Education in any situation | 3 | | 4 | 7 | 8.14 |
| | Lessoning | | 2 | 1 | 3 | 3.49 |
| | Improving the use of technology | 2 | 1 | | 3 | 3.49 |
| | The importance of distance education | | 2 | 1 | 3 | 3.49 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Taking courses online | 1 | 1 | | 2 | 2.33 |
| | Generating new solutions for education | 1 | | | 1 | 1.16 |
| | Playing a more active role in education | 1 | | | 1 | 1.16 |
| | Making education fun | | 1 | | 1 | 1.16 |
| | Necessity of using technology in mathematics | | | 1 | 1 | 1.16 |
| | The importance of technological competence | | 1 | | 1 | 1.16 |
| | Increasing interest in technology | | 1 | | 1 | 1.16 |
| | Total | 15 | 27 | 26 | 68 | 79.07 |
| Negative | Mathematics should not be completely online | 5 | 1 | 1 | 7 | 8.14 |
| | Access to technology is not equal | | 2 | | 2 | 2.33 |
| | Online is harder | 1 | | | 1 | 1.16 |
| | Total | 6 | 3 | 1 | 10 | 11.63 |
| | No opinion | 6 | 1 | 1 | 8 | 9.30 |
| | Grand Total | 27 | 31 | 28 | 86 | 100.00 |

According to table 12, the vast majority of EMTCs reported positive views on the use of DTs during the COVID-19 pandemic (n=68, 79.07%). The most emphasized thought among the positive opinions is "seeing the necessity of technology" (n=28, 32.56%). Afterward, with the COVID-19 pandemic, most opinions are “Extending the use of technology" and "Recognizing the lack of technology" (n=8, 9.30%). Most of the EMTCs who gave negative opinions expressed the view that "mathematics should not be completely online" based on their experiences of online courses during the COVID-19 pandemic (n=7, 8.14%). Some of the opinions of EMTCs regarding the codes in table 12 are given below:

P41: “*I saw that digital technologies are more important when all courses are online with COVID19*” (Seeing the necessity of technology)

P11: “*After the covid, those who do not know technology had to use it, it was included in our lives too much*” (Disseminating the use of technology)

P39: “*I did not think that there was such a need before, but after that, I saw how useful the use of digital technologies was”* (Recognizing the lack of technology)

P52: “*I am once again convinced that mathematics should not be taught entirely online. Digital support is important, but not purely digital*.” (Mathematics should not be completely online)

6. What are your thoughts on the use of DTs in mathematics lessons through distance education?

Due to COVID-19, distance education has been started in Türkiye as well as in the rest of the world. Lessons in higher education were also held on an online basis. In this context, the views of ECMTs on the use of digital technologies in online lessons were asked. The answers given by the participants are given in table 13:

**Table 13.**

Finding of the using digital technology in distance mathematics education

| Theme | Code | 2nd Grade | 3rd Grade | 4th Grade | Total | % |
|---|---|---|---|---|---|---|
| Positive | Increasing interest and motivation | | 2 | 8 | 10 | 12.05 |
| | Effective lesson | 2 | 4 | 1 | 7 | 8.43 |
| | Positive attitude | | 3 | 3 | 6 | 7.23 |
| | Good experience | 4 | | | 4 | 4.82 |
| | Providing comfort | 1 | | 3 | 4 | 4.82 |
| | Beneficial | 1 | 2 | 1 | 4 | 4.82 |
| | It provided concretization | 1 | 2 | | 3 | 3.61 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Lesson repetition | | 2 | | 2 | 2.41 |
| | Lesson efficiency | 1 | 1 | | 2 | 2.41 |
| | Enjoyable | | 1 | | 1 | 1.20 |
| | Its use should be increased | | 1 | | 1 | 1.20 |
| | Motivation booster | | | 1 | 1 | 1.20 |
| | Ease of earning | | 1 | | 1 | 1.20 |
| | Developing creative thinking | | 1 | | 1 | 1.20 |
| | Saving on time | 1 | | | 1 | 1.20 |
| | Total | 11 | 20 | 17 | 48 | 57.83 |
| Negative | Inefficient | 3 | 5 | 1 | 9 | 10.84 |
| | Can be used better | 1 | 2 | 4 | 7 | 8.43 |
| | Digital technologies are not used sufficiently | | | 2 | 2 | 2.41 |
| | Internet problem | 1 | 1 | | 2 | 2.41 |
| | More efficient face to face | 2 | | | 2 | 2.41 |
| | Compelling | 2 | | | 2 | 2.41 |
| | Nothing has changed | 1 | | | 1 | 1.20 |
| | Active participation should be ensured | 1 | | | 1 | 1.20 |
| | Boring | | 1 | | 1 | 1.20 |
| | Total | 11 | 9 | 7 | 27 | 32.53 |
| | No İdea | 4 | 1 | 3 | 8 | 9.64 |
| | Grand Total | 26 | 30 | 27 | 83 | 100.00 |

Within the framework of the findings obtained, it is seen that EMTCs mostly expressed positive opinions about the use of DTs in mathematics lessons conducted through distance education. In this context, 48 out of 83 (57.83%) opinions reveal that the use of DTs in mathematics education is positive. The opinions of the EMTCs regarding the findings obtained are presented below:

P57: "*The use of digital technologies is necessary and important. Using plain lectures in distance education will not keep the student in the class. The use of activity-based and ICT will provide motivation. In addition, a more constructivist education will be provided compared to plain lectures.*" (Increasing interest and motivation)

P1: "*I think distance learning mathematics courses using digital technology are more effective*." (Effective lesson)

P37: "*I think it was insufficient, we were compelled before we were ready for distance education, which caused us to have problems as it was not a customary situation*." (Inefficient)

P22: "*It could have been used more effectively and conspicuously, but I think it was not used well enough*" (Can be used better)

*4.3. Findings related to the third research problem: The effect of DTs*

The third problem of the research is about the use of digital technologies in the mathematics education of teacher candidates. In this context, open-ended questions were asked to EMTCs about which DTs could be used in mathematics education and for what purposes, and which concepts or subjects could be used in mathematics education. In this context, the findings obtained for the open-ended questions are presented below within the framework of the related open-ended questions.

7. Which DTs can be used in mathematics education?

The opinions of EMTCs about which DTs can be used in mathematics education within the framework of their experiences and undergraduate education were also taken within the framework of the research. In this context, the findings for the analysis carried out in line with the data obtained from EMTCs are presented in figure 5 and table 14:

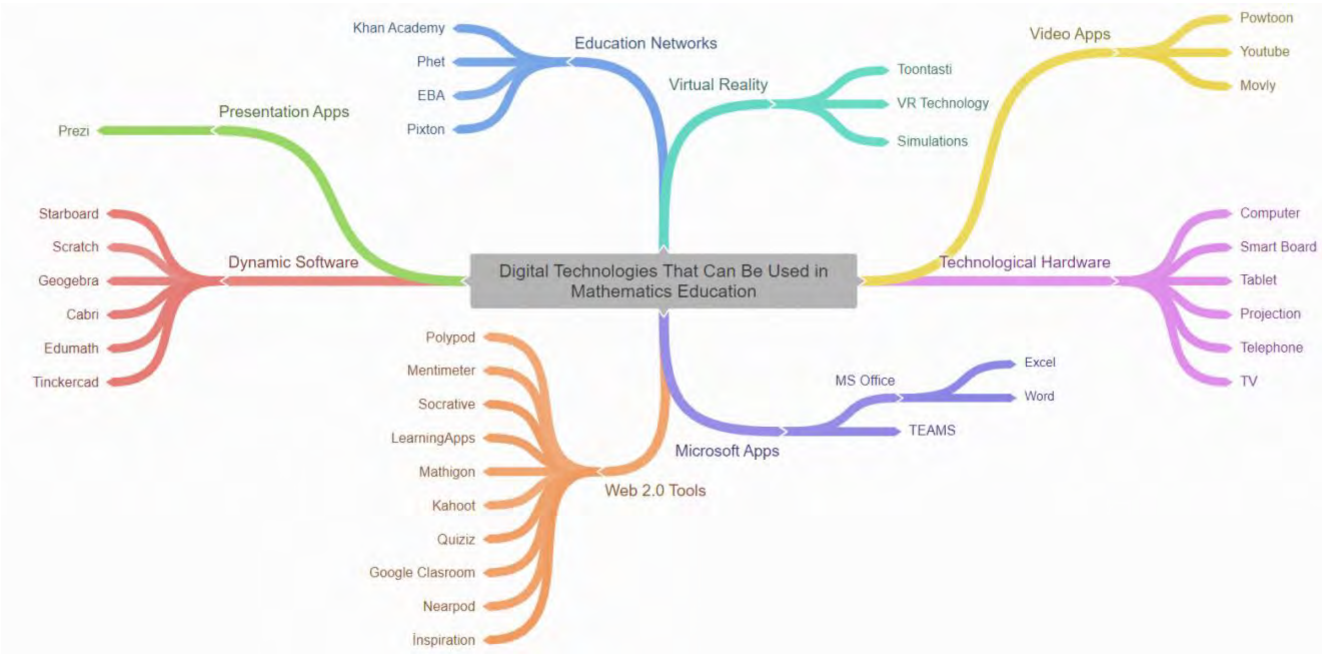


**Fig. 5.** DTs that can be used in mathematics education

**Table 14.**

Findings on DTs that can be used in mathematics education

| Thema | Code | 2nd Grade | 3rd Grade | 4th Grade | Total | % |
|---|---|---|---|---|---|---|
| Web 2.0 Tools | Web 2.0 Tools | | 9 | 10 | 19 | 11,45 |
| | Mathigon | | 4 | 7 | 11 | 6,63 |
| | Kahoot | 1 | 6 | 3 | 10 | 6,02 |
| | LearningApps | 1 | 5 | 3 | 9 | 5,42 |
| | Quizizz | 1 | 1 | 1 | 3 | 1,81 |
| | Socrative | | 1 | 2 | 3 | 1,81 |
| | Google classroom | | | 2 | 2 | 1,20 |
| | Mentimeter | | 1 | 1 | 2 | 1,20 |
| | Nearpod | | | 2 | 2 | 1,20 |
| | Polypod | | 2 | | 2 | 1,20 |
| | Inspiration | | 1 | | 1 | 0,60 |
| | Total | 3 | 30 | 31 | 64 | 38,55 |
| Dynamic Software | GeoGebra | 4 | 15 | 14 | 33 | 19,88 |
| | Cabri | 1 | 3 | 3 | 7 | 4,22 |
| | Scratch | | 1 | 1 | 2 | 1,20 |
| | Edumath | | | 1 | 2 | 1,20 |
| | Starboard | | 1 | | 1 | 0,60 |
| | Tinckercad | | | 1 | 1 | 0,60 |
| | Total | 5 | 20 | 21 | 46 | 27,71 |
| Technological Hardware | Computer | 11 | 4 | 2 | 17 | 10,24 |
| | Smartboard | 1 | 1 | 2 | 4 | 2,41 |
| | Tablet | 4 | | | 4 | 2,41 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Projection | 1 | | 1 | 2 | 1,20 |
| | Telephone | 1 | | | 1 | 0,60 |
| | TV | 1 | | | 1 | 0,60 |
| | Total | 19 | 5 | 5 | 29 | 17,47 |
| Microsoft Apps | TEAMS | 2 | 2 | 1 | 5 | 3,01 |
| | Microsoft Office | | 2 | 1 | 3 | 1,81 |
| | Excel | | | 1 | 1 | 0,60 |
| | Word | 1 | | | 1 | 0,60 |
| | Total | 3 | 4 | 3 | 10 | 6,02 |
| Education Networks | Phet | | | 3 | 3 | 1,81 |
| | EBA | | 1 | | 1 | 0,60 |
| | Khan Academy | | 1 | | 1 | 0,60 |
| | Pixton | | | 1 | 1 | 0,60 |
| | Total | 0 | 2 | 4 | 6 | 3,61 |
| Virtual Reality | VR Technology | | 3 | | 3 | 1,81 |
| | Simulations | | 1 | | 1 | 0,60 |
| | Toontastic | | | 1 | 1 | 0,60 |
| | Total | 0 | 4 | 1 | 5 | 3,01 |
| Presentation Apps | Prezi | | 1 | 2 | 3 | 1,81 |
| Video Apps | Movly | | 1 | | 1 | 0,60 |
| | Powtoon | | | 1 | 1 | 0,60 |
| | Youtube | 1 | | | 1 | 0,60 |
| | Total | 1 | 1 | 1 | 3 | 1,81 |
| | Grand Total | 31 | 67 | 68 | 166 | 100,00 |

According to table 14 and figure 5, EMTCs expressed an opinion that DT tools such as "Web 2.0 tools", "Dynamic software", "Technological hardware", "Microsoft apps", "Educational networks", "Virtual reality" applications, "Presentation apps" and "Video apps" can be used in mathematics education. It has been concluded that the most mentioned DT tools are Web 2.0 tools (n=64, 38.55%), while applications such as Mathigon, Kahoot, LearingApss are more expressed for Web 2.0 tools than other tools. In terms of dynamic software, the GeoGebra application represents almost 20% of all opinions (n=33, 19.88%). In the theme of technical hardware, "Computer", which is a digital technology tool, stands out (n=17, 10.24%).

8. For what purpose can DTs be used in mathematics education?

Another question posed to EMTC within the framework of the third research problem on the use of DTs in mathematics education is about the purpose for which DTs can be used in mathematics education. In this context, the findings obtained by analysing the answers of EMTCs are presented in table 15:

**Table 15**

Findings for what purpose can DTs be used in mathematics education

| Theme | Code | 2nd Grade | 3rd Grade | 4th Grade | Total | % |
|---|---|---|---|---|---|---|
| Education | Lesson repetition | | 1 | | 1 | 0,86 |
| | Reaching large audiences | 1 | | | 1 | 0,86 |
| | Total | 1 | 1 | | 2 | 1,72 |
| Learning | Permanent learning | 1 | 5 | 3 | 9 | 7,76 |
| | Fun lesson | 2 | 5 | 1 | 8 | 6,90 |
| | Reinforcement | 1 | 3 | | 4 | 3,45 |
| | Evaluation | | 3 | | 3 | 2,59 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Meaningful learning | | 1 | 1 | 2 | 1,72 |
| | Ensuring intelligibility | 1 | | | 1 | 0,86 |
| | Deepening | | 1 | | 1 | 0,86 |
| | Clearing misconceptions | | 1 | | 1 | 0,86 |
| | Homework | 1 | | | 1 | 0,86 |
| | Total | 6 | 19 | 5 | 30 | 25,86 |
| Teaching | Concretization | 13 | 13 | 6 | 32 | 27,59 |
| | Effective teaching | 2 | 5 | 6 | 13 | 11,21 |
| | Graph function drawing | 3 | | 2 | 5 | 4,31 |
| | Draw attention | 1 | | 3 | 4 | 3,45 |
| | Arouse interest | | 1 | 3 | 4 | 3,45 |
| | Gamification | | 3 | | 3 | 2,59 |
| | Active participation | | 2 | | 2 | 1,72 |
| | Affordability | 2 | | | 2 | 1,72 |
| | Motivation | 1 | 1 | | 2 | 1,72 |
| | Exploring | | 2 | | 2 | 1,72 |
| | Modeling | | 1 | 1 | 2 | 1,72 |
| | Enriching teaching | | 1 | 1 | 2 | 1,72 |
| | Developing a positive attitude | | 2 | | 2 | 1,72 |
| | Project and design | 2 | | | 2 | 1,72 |
| | Attribution | | 1 | | 1 | 0,86 |
| | Demonstration with proof | | | 1 | 1 | 0,86 |
| | Material design | | 1 | | 1 | 0,86 |
| | Increase motivation | 1 | | | 1 | 0,86 |
| | Making an application | | 1 | | 1 | 0,86 |
| | Teaching with video | 1 | | | 1 | 0,86 |
| | Configuration | | 1 | | 1 | 0,86 |
| | Total | 26 | 35 | 23 | 84 | 72,41 |
| | Grand total | 33 | 55 | 28 | 116 | 100,00 |

According to table 15, it is seen that DTs can be used in mathematics education within the framework of education, teaching, and learning purposes. In terms of teaching, the most mentioned subject regarding DTs by EMTCs is about "Concretization" (n=32, 27.59%). Next comes "effective teaching" (n=13, 11.21%). In terms of learning, the most mentioned subject regarding the use of DTs in mathematics education is about "permanent learning" (n=9, 7.76%). Afterward, it emerged that DTs could be used in mathematics education to make learning fun lesson (n=8, 6.90%). The opinions of some EMTCs regarding the findings in table 15 are given below:

P28: "*Abstract situations can be concreted in order to animate 3D drawings*" (Concrete)

P61: "*I think that teaching with digital technologies makes it effective.*" (Effective teaching)

P6: "*Digital technologies for permanent learning can be used in mathematics education.*" (Permanent learning)

P11: "*It can make the lesson fun*" (Fun lesson)

9. Which mathematical concepts or subjects are suitable to use DTs for teaching?

Another question posed to EMTCs within the framework of the third research problem is about which mathematical concepts or subjects can be used in teaching DTs. In this context, the findings obtained within the framework of the analysis regarding the answers of EMTCs are presented in Figure 6 and Table 16.

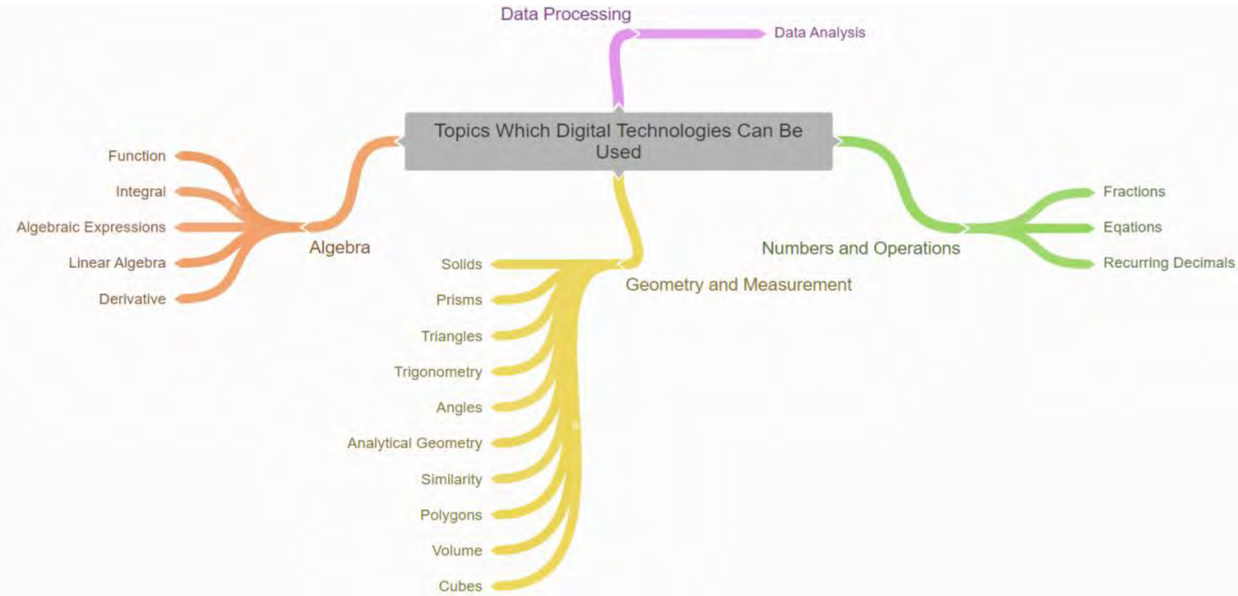


**Fig. 6** Topics which digital technologies can be used

**Table 16.**

Findings on the topics that DTs can be used in mathematics education

| Theme | Code | 2nd Grade | 3rd Grade | 4 Grade | Total | % |
|---|---|---|---|---|---|---|
| Geometry and Measurement | Geometry | 8 | 12 | 19 | 39 | 42,86 |
| | Solids | 2 | 1 | 2 | 5 | 5,49 |
| | Prisms | | | 3 | 3 | 3,30 |
| | Triangles | 2 | 1 | | 3 | 3,30 |
| | Trigonometry | 2 | | | 2 | 2,20 |
| | Angles | | 1 | | 1 | 1,10 |
| | Analytical geometry | 1 | | | 1 | 1,10 |
| | Similarity | | 1 | | 1 | 1,10 |
| | Polygons | 1 | | | 1 | 1,10 |
| | Volume | 1 | | | 1 | 1,10 |
| | Cubes | | 1 | | 1 | 1,10 |
| | Total | 17 | 17 | 24 | 58 | 63,74 |
| Algebra | Algebra | 3 | 5 | 1 | 9 | 9,89 |
| | Function | 2 | | | 2 | 2,20 |
| | Integral | 2 | | | 2 | 2,20 |
| | Algebraic expressions | 1 | 1 | | 2 | 2,20 |
| | Linear algebra | 1 | | | 1 | 1,10 |
| | Derivative | | 1 | | 1 | 1,10 |
| | Total | 9 | 7 | 1 | 17 | 18,68 |
| Numbers and Operations | Fractions | 2 | | | 2 | 2,20 |
| | Equations | | | 1 | 1 | 1,10 |
| | Recurring decimals | | | 1 | 1 | 1,10 |
| | Total | 2 | 0 | 2 | 4 | 4,40 |
| Data processing | Data analysis | | 1 | | 1 | 1,10 |
| | All topics | | 6 | 5 | 11 | 12,09 |
| | Grand Total | 28 | 31 | 32 | 91 | 100 |

According to figure 6 and table 16, EMTCs state that DTs will be used in applications related to "Geometry and measurement", "Algebra", "Numbers and operations" and "Data processing". More than half of the opinions on the subjects on which DTs can be realized in mathematics education were expressed in the field of geometry and measurement (n=58, 63.74%). When the opinions about geometry and measurement were examined, the majority of EMTCs stated that DTs could be used in geometry subjects (n=39, 42.86%). After the "Geometry and Measurement" learning area, the subject area in which EMTCs expressed the most opinions about the use of DTs is Algebra (n=17, 18.68%). It is seen in Table 16 that the least expressed subject area is "Data Processing". It is a remarkable result that EMTCs did not express their opinions on statistics and probability. Another remarkable finding is that 11 EMTCs stated that DTs can be used in all subjects.

## 5. Discussion and Conclusion

In our age, where digital technologies and digitalization are popular and digital technologies have left their mark on the 21st century, social, economic, and political fields have entered a tremendous change through DTs (Saykili, 2019). It was inevitable that education would not be affected by this change. In other words, DTs continue to affect other fields as well as in the field of education (Borba, 2021). It is stated that while the rapid integration of DTs in all areas of life is realized, the speed of integration in the field of education remains constant (Ng, 2015). In order to accelerate the integration of DTs into education, the readiness and technological infrastructure of teachers and teacher candidates for DTs should be brought to a sufficient level. There are some weaknesses in the use of DTs as there is not enough support for technology and technology use in the teacher education process (Gruszczynska et al., 2013). In this context, the effect of undergraduate courses for teacher education on the use of DTs and the opinions of teacher candidates on DTs should be reviewed. This study aimed to determine the thoughts of teacher candidates on the use of DTs. For this purpose, the effect of undergraduate education on the use of DTs, the effect of COVID-19 on the use of DTs, and the effect of DTs on mathematics education were examined.

As a result of the examinations, it was seen that the majority of EMTCs did not encounter DTs in their lessons before their undergraduate education. It can be said that this finding supports the view that teachers are unsuccessful in integrating technology into their lessons (Bozkurt & Cilavdaroğlu, 2011; Ertmer et al., 2012; Ulaş & Ozan, 2010; Zhao et al., 2022). This shows that teachers' proficiency in using DTs is low (Kaldırım & Tavşanlı, 2021). If teachers do not receive training on the use of DTs in undergraduate courses or DTs are not used in undergraduate courses, it will be difficult for them to use such technologies in their teaching life, as they are not familiar with DTs.

EMTCs stated that DTs were used for entertainment purposes as well as education, training, and learning areas for the use of DTs before their undergraduate education. In this context, it supports the idea that DTs contribute to every field of education (Öztop & Özerbaş, 2019). It is seen that the views on technology use after undergraduate education are considerably higher than the views on technology use before undergraduate education, and the usage areas of DTs are more detailed after undergraduate education. When the use of DTs before undergraduate education is examined, although the views on learning are close to the views on teaching, the views on teaching in the use of DTs after undergraduate education are almost four times higher than the views on learning. It is important to train pre-service teachers for DTs and to develop their "digital technology selection" skills (Gonscherowski & Rott, 2022). This is an indication that undergraduate education has a positive effect on the use of technology by EMTCs. In addition, it is seen that the number of those who think not to use DTs decreases as the class level of teacher candidates increases. It is a remarkable result that all fourth-grade students stated that they could use DTs in mathematics education. In this case, it is thought to be another finding that shows the effect of undergraduate education on the use of DTs.

In line with the opinions of EMTCs obtained within the framework of their undergraduate education, they emphasized that DTs can be used in terms of education, training, learning, and technology. Facilitation, concretization, attract attention, and supporting the lesson are the most frequently mentioned reasons for teaching, among the reasons for using DTs after undergraduate education. This is an indication that the use of technologies in mathematics education can support the interpretation of mathematical concepts (İnce-Muslu & Erduran, 2020).

Teacher candidates' training is noteworthy in terms of developing knowledge and skills for DTs (Gonscherowski & Rott, 2022). In this context, it has been concluded that undergraduate education teacher candidates support their use of technology in terms of pedagogical, content, and technology. It is a remarkable finding that in the future, learning and teaching activities will be more based on digital teaching technologies (Şen & Havva, 2020), supporting teacher candidates in terms of technological, pedagogical, and mathematics course content. EMTCs, who are also the participants of this study, take more than 60 courses during their undergraduate education. When the views on the courses that contribute to the use of DTs in undergraduate education are examined, it has been revealed that various opinions are presented regarding the contribution of 16 courses to DTs in total. This rate does not exceed 25% in all undergraduate courses. In this context, it is thought that the widespread use of digital technology in undergraduate courses will contribute to the decision of educators when the role and use of DTs in life is increasing gradually (Gonscherowski & Rott, 2022).

One of the topics examined in the research was related to the impact of the COVID-19 pandemic on the use of DTs in mathematics education. With the impact of COVID-19, not only social life, economy, labor, and art, but also education was adversely affected. In this context, education was suspended in many schools due to the epidemic. Within the framework of these decisions of the field all over the world, in order to reduce the negative effects of the COVID-19 epidemic in education, a direction towards online education has started from the trainings that cannot be held face-to-face. It has shown the importance of DTs in mathematics education by taking the agenda of the DT trend in mathematics education as well as the negative effects of COVID-19 (Borba, 2021). The opinions of the EMTCs in the research on the use of DTs in mathematics education regarding COVID-19 support the opinion of Borba (2021). 90% of EMTCs stated that the COVID-19 epidemic affected the use of DTs in mathematics education. This finding is consistent with the findings of Alabdulaziz (2021). In addition, within the framework of the findings, it can be said that COVID-19 opened a door for the use of DTs in mathematics education (Alabdulaziz, 2021).

Another situation examined in the study is the usage areas of DTs in mathematics education and DTs that can be used in mathematics education. In this context, it has been concluded that many digital technological tools such as web 2.0 tools, dynamic software, technological hardware, Microsoft apps, education networks, virtual reality, presentation, and video apps can be used in mathematics education. Within the framework of these tools, students' interest and motivation towards mathematics education can be increased (Öztop, 2022). According to the findings, it was concluded that the most expressed digital technology tool was GeoGebra. Within the framework of using GeoGebra in mathematics education, students can better understand mathematics lessons, and lessons can be made interesting and entertaining (Kutluca & Zengin, 2011). Visual and dynamic teaching can be provided by means of digital technology tools.

Although opinions on almost all learning areas on which subjects DTs can be used in mathematics education, more views were expressed in the field of geometry and measurement learning. In addition, the opinion of the majority that DTs can be used in geometry is remarkable. Due to the abstract nature of the subjects in the field of geometry learning, students have difficulty constructing geometric structures in their minds (Şeker & Erdoğan, 2017). DTs can be used to overcome this challenge. In addition, it can be said that the majority view on the use of DTs in geometry subjects and the fact that the "concrete" view on the question of what purpose DTs can be used in mathematics education is more than the other ideas.

## 6. Suggestions

Many of EMTCs in the research state that they did not encounter DTs in their education life before their undergraduate education. This may be an indication that DTs are not used sufficiently in high school and secondary school mathematics education. It is recommended to popularize DTs in secondary and high school mathematics education.

95% of EMTCs participating in the research emphasized that they would use DTs in mathematics education after undergraduate education. This is an indication that DTs have an important place in mathematics education. However, it can be said that the courses that require the use of digital technology for undergraduate education are not sufficient. In this context, courses on the use of digital technologies in undergraduate courses should be expanded. When the grade levels of the teacher candidates who expressed a negative opinion about the use of DTs in mathematics education within the framework of their undergraduate education were examined, it was concluded that the second-grade teacher candidates were generally the ones who viewed technology negatively and that EMTCs expressed more positive and more opinions about DTs as the grade level increased. In this context, it is recommended to use DTs in the 1st and 2nd grades in undergraduate education and to expand the courses in this context.

As a result of the research, it was concluded that COVID-19 opened the door to the use of DTs in mathematics education. In this context, studies can be carried out at primary, secondary, high school, and university levels to determine the extent to which DTs are used in mathematics education by COVID-19.

Opinions have been put forward that DTs can be used in almost every subject area in mathematics education. The effect of DTs on learning areas and subject areas can be investigated. In addition, EMTCs' views on the use of digital technologies on statistics and probability issues were not presented. In this context, studies on the use and impact of DTs on statistics and probability can be carried out.

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## Appendix

### Open-ended Questions on the Use of Digital Technologies in Mathematics Education of Elementary Mathematics Teacher Candidates

1. Did you use DT in mathematics education before your undergraduate education? If so, for what purpose did you use it?

2. Do you intend to use DT in mathematics education after your undergraduate education? Why?

3. Do you think that your undergraduate lessons have an impact on the use of DT in mathematics education? Why?

4. Which of your undergraduate courses have contributed to the use of digital technology in mathematics education? Explain in what context this contribution is made.

5. Has the COVID-19 pandemic affected your thoughts on the use of DT in mathematics education? What are your grounds?

6. What are your thoughts on the use of DT in mathematics lessons through distance education?

7. Which DT can be used in mathematics education?

8. For what purpose can DT be used in mathematics education?

9. Which mathematical concepts or subjects are suitable to use DT for teaching?