# EXAMINATION OF TURKISH MATHEMATICS TEACHERS TECHNOLOGY INTEGRATION LEVELS AND THEIR SELF-CONFIDENCE IN TPACK*

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**ABSTRACT**

The purpose of this study is to investigate secondary mathematics teachers' level of technology integration and their confidence in TPACK related to technology components. Fifty-seven mathematics teachers participated in the present study, which used the convergent parallel mixed method design. A written opinion form to elicit teachers' views and the TPACK self-confidence survey were used as data collection instruments in the study. It was found that teachers have moderate self-confidence and majority of them integrate technology in their teaching at the replacement level. It was also found that teachers' TPACK self-confidence did not differ according to their level of technology integration. However, there was a significant difference in the TPACK component of participants' TPACK self-confidence in favor of those who agreed with the idea that students should use technology tools in the classroom. Similarly, mathematics teachers who use more than one software in their teaching were found to have significantly higher TPACK self-confidence in all components. Consequently, it can be said that the level of technology integration of mathematics teachers is reflected in their TPACK self-confidence.

**Keywords:** *Mathematics teachers, mathematics education, teacher confidence, TPACK, technology integration.*

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## INTRODUCTION

In the age we live, we witness the beginning of a new era in educational activities. Fletcher (2003) emphasizes three revolutions that shape educational activities. The first is the invention of the written language. With the invention of the written language, consulting the sages was not the only way to access information anymore and information became available to anyone who had access to written sources. The second major impact was caused by the portability of written information and the printing of books. Books made information accessible, available, and relatively low-cost for everyone. The third revolution of which we are on the verge is technology-based education. Thanks to the integration of technology into education, access to quality information has become easier and interactive. In this way, by saving time and cost in the learning process, it is possible to achieve a more practical education for all students by considering individual differences (Fletcher, 2003).

In short, technology integration, defined as the integration of technology into the teaching and learning process (Cerniamo, Ross & Ertmer, 2010), is the incorporation of technology into the educational process to reinforce learning on a particular topic, becoming a part of the teaching activity and accessible like other educational tools (International Society for Technology in Education, 2000). Hughes (2005) stated that technology integration is realized at three levels in teaching and learning processes. The first is the “replacement" level, where technology integration only provides an environmental change in the teaching and learning process. The activities carried out at this level do not lead to any change in students’ learning routines; technology is used without targeting different objectives or achievements, and the educational activities can be performed without technology integration (Akkoç, Özmantar, Bingölbali, Demir, Baştürk & Yavuz, 2011; Demir & Özmantar, 2013). For example, if a mathematics teacher displays a definition or exercise on any topic on the screen using tools such as smartboards or projectors instead of writing them on the blackboard, this is a replacement-level application. The second is the level of “Amplification,” where facilitation of the learning process with the technology integration is aimed at. At the amplification level of technology integration, which does not usually require drastic changes in classroom routines and practices, it is aimed to ensure more effective and faster execution of a number of activities without any change in tasks or objectives in the teaching and learning process (Akkoç et al., 2011; Demir & Özmantar, 2013). When a mathematics teacher draws graphs of quadratic functions quickly and accurately using Mathematica software while teaching the topic of parabolas, this can be seen as an example of technology integration at the level of amplification (Ardıç & İşleyen, 2017a).The highest level of technology integration is called the “transformation” level. In a classroom where the technology integration is at the transformation level, it is aimed that students understand the conceptual structures in mathematics and establish internal connections between these structures (Akkoç et al., 2011). According to Hughes (2005), teachers need to change their pedagogical approaches and classroom routines to achieve technology integration at the high level and provide deep learning. For example, a transformation-level practice is to allow students to use appropriate computer software and have them use the method of trial and error with a student-centered approach when learning "whether a graph of the function f(x)=ax^2+bx+c is convex or concave depends on whether a is positive or negative" (Ardıç & İşleyen, 2017a). With such a level of technology integration, the teacher can go beyond classroom routines, take advantage of the dynamic features of computer software, enable students to experience that the result obtained is correct for all parabola, and help them to develop deeper conceptual understanding.

Ertmer (1999) emphasized two levels of barriers that prevent teachers from achieving technology integration in their classrooms: external (first-order) and internal (second-order) barriers. “External barriers” can be summarized as teachers’ inability to access the hardware and software they need and receive the necessary technical and administrative support and the lack of appropriate teaching plans. “internal barriers” relate to teachers’ self-confidence and their belief in themselves and in the teaching-learning activities. Teachers' beliefs about technology integration, existing instructional and classroom routines, and change are examples of “internal barriers”. It is believed that in the process of technology integration, overcoming “external barriers” is relatively easier than overcoming “internal barriers” (Ertmer, 1999). In fact, over the last three decades, many governments worldwide have spent considerable amounts of money and human resources to overcome “external barriers” by improving technological opportunities in schools (Cattagni & Farris, 2001; Etmer et al., 2012; Göktaş, Gedik & Baydaş, 2013). In this context, Turkey's Ministry of National Education (MONE) implemented the FATİH (Movement to Increase Opportunities and Technology) project. Within the project's scope, the technological infrastructure of classrooms was developed, internet access was provided, interactive (smart) boards were installed, and tablet computers were distributed to students in many schools. In this way, it was aimed to enable students to use different sensory organs in the teaching and learning process through the effective use of information and communication technologies in education and training activities and thus to ensure equal opportunities in education (MONE, 2013). Although it has been observed that “external barriers” in the technology integration process have been overcome to a great extent thanks to projects such as FATIH carried out in many countries, “internal barriers” still assume a decisive role in this process (Ertmer et al., 2012; Göktaş, Gedik & Baydaş, 2013; Ottenbreit-Leftwich, Liao, Sadik & Ertmer, 2018). From this point of view, to achieve the desired level of technology integration in educational activities, current integration levels and “internal barriers” of teachers need to be determined. Moreover, studies to be carried out with this aim can give governments insight into using their money and human resources more effectively for technology integration.

In the studies conducted to determine teachers' "internal barriers", teachers' self-efficacy and self-confidence in integrating technology into the classroom are the primary concerns (Ertmer & Ottenbreit-Leftwich, 2010). Although teachers have sufficient technological knowledge and devices, they cannot achieve the desired impact on teaching activities if they lack self-confidence (Ertmer & Ottenbreit-Leftwich, 2010; Voogt, Fisser, Pareja-Roblin, Tondeur & Braak, 2013). Bandura (1977) defined the concept of self-efficacy as a person's belief in their ability to perform a particular task. Bandura also stated that a person is only able to effectively demonstrate their abilities in a specific domain if he or she has self-confidence in that domain. In other words, self-efficacy is a person's belief in overcoming a problem or accomplishing a particular task. On the other hand, self-confidence can be defined as a person's subjective assessment of their own worth and opinion of their abilities. In this regard, self-confidence can be considered as a measure of self-efficacy (Bandura, 1986).

Integrating technology into educational activities is a "complex, dynamic, slow, and long-term" process, regardless of the desired level of technology integration (Groff & Mouza, 2008; Koehler, Mishra & Yahya, 2007). One of the main problems in technology integration is that "pedagogy" and "technology" are treated as separate fields (Koehler & Mishra; 2008). From this perspective, "pedagogy" is the responsibility of teachers, while "technology" is the responsibility of technology experts. However, in the technology integration process, it is not only the teacher or only the technology expert who is responsible. The responsibility is distributed among all components of the integration process, including the technology tools. Given the relationships among these components, theoretical frameworks and models developed to understand and improve the process can be used to solve the problems that arise during the technology integration process (Koehler, Mishra & Yahya, 2004). "Technological Pedagogical Content Knowledge" (TPACK), developed by Koehler and Mishra (2005), is one of these frameworks.

The TPACK framework, which focuses on the components of "technology", "pedagogy", and "content" knowledge, assumes that the integration of technology into the educational process results from the dynamic relationships among these components and describes how this interaction occurs (Mishra & Koehler, 2006). TPACK is in fact, a theoretical framework developed with the addition of the component "Technology Knowledge" (TK) to "Pedagogical Content Knowledge" (PCK), first introduced by Shulman (1986). As a result of the interaction of TK with the PCK, the components "Technological Pedagogical Knowledge" (TPK) and "Technological Content Knowledge" (TCK) have emerged alongside the TPACK. "TK" is a general knowledge and skills of teachers to use technologies at all levels, from standard technologies (such as blackboards) to advanced technologies (such as Internet and computers) (Bingoelbali, Özmantar, Sağlam, Demir & Bozkurt, 2012). According to Mishra and Kohler (2006), "TK" includes advanced technological knowledge, such as knowledge of hardware and software, how to install and uninstall software, and the ability to solve basic problems that have occurred. On the other hand, "TCK" is a teacher's knowledge about the technology they can use in teaching a subject, about what technology is most appropriate in teaching a particular subject, and about the possibilities and limitations of the technology to be used (Koehler & Mishra, 2009). "TPK" is the knowledge of how teaching and learning activities are affected when certain technologies are used in certain ways (Koehler & Mishra, 2009). "TPK" also includes knowledge about the pedagogical approaches that are appropriate for the technologies in question and the capabilities and limitations of the tools used (Mishra & Koehler, 2006). "TPACK", which is the interaction of the three main components "content", "technological" and "pedagogical" knowledge can be defined as a teacher's knowledge of using technological equipment for a particular subject to facilitate student learning (Bingoelbali et al., 2012).

An examination of national (Baran & Canbazoğlu Bilici, 2015; Dikmen & Demirer, 2016; Kaleli Yılmaz, 2015) and international literature reviews (Abbitt, 2011; Chai, Koh & Tsai, 2013; De Rossi & Trevisan, 2018; Tondeur et al., 2012; Wu, 2013; Voogt et al., 2013) surveying the studies on TPACK will be useful for revealing the current situation. It was found that a majority of these studies enrolled prospective teachers as participants (Baran & Canbazoğlu Bilici, 2015; Dikmen & Demirer, 2016; Kaleli Yılmaz, 2015; Wu, 2013). It was also found that the vast majority (80%) of the studies conducted at the national level (Baran & Canbazoğlu Bilici, 2015) included prospective teachers, while no study included secondary mathematics teachers as participants (Baran & Canbazoğlu Bilici, 2015; Dikmen & Demirer, 2016; Kaleli Yılmaz, 2015). The paucity of studies that included teachers as participants makes it difficult to understand current classroom practices related to TPACK and technology integration.The majority of the studies on TPACK in Turkey consist of those conducted to develop and adapt scales and to determine TPACK levels. On the other hand, it is seen that the number of studies focused on a specific subject area or branch is quite low (Kaleli Yılmaz, 2015). While national studies have mostly used quantitative methods (Baran & Canbazoğlu Bilici, 2015; Dikmen & Demirer, 2016; Kaleli Yılmaz, 2015), international studies have mostly used qualitative methods (Chai et al., 2013) and studies using mixed research design are quite rare (Abbitt, 2011; Dikmen & Demirer, 2016). Moreover, it can be seen that both national (Baran & Canbazoğlu Bilici, 2015; Dikmen & Demirer, 2016; Kaleli Yılmaz, 2015) and international studies (Abbitt, 2011; De Rossi & Trevisan, 2018) frequently use data collection tools such as surveys and scales that focus on self-assessment. One thing that deserves attention here is that in the quantitative studies conducted at the national level using surveys and scales, participants showed high levels of TPACK, TPACK efficacy, and TPACK perception, while in the qualitative studies conducted at the national level using data collection tools such as observation and interviews, the results were just the opposite (Kaleli Yılmaz, 2015). Several studies suggest that self-assessment scales for TPACK, when used alone, are more likely to measure the TPACK participants believe they have rather than their actual TPACK (Abbitt, 2011; Kaya & Kaya, 2013). Considering these factors, the use of mixed methods research using data collection tools such as interviews or observations rather than quantitative research methods using only self-report scales may allow for more accurate results in the studies to be conducted. In fact, as a result of their literature review, Tondeur et al. (2012) found that it is possible to address concerns about understanding and assessing the theoretical structure of TPACK by using mixed research methods.

Achieving the desired level of technology integration in mathematics education requires instructional practices that require the adoption of a theoretical framework such as TPACK and are free of “external” and “internal barriers”. Today, it can be assumed that the “external barriers” have been or are being largely overcome. Therefore, the theoretical framework, teacher confidence, and instructional practices come to the forefront in achieving the desired level of technology integration in mathematics education. However, there is no holistic approach to this situation in the literature and there are no studies that address this issue specifically for secondary mathematics teachers. To address this gap in the literature, this study examined secondary mathematics teachers' level of technology integration and TPACK self-confidence.

**Research Questions**

In this study, which aimed to determine to what extent secondary education mathematics teachers integrate technology into their classes and their TPACK self-confidence levels in terms of technology components, answers to the following questions were sought:

Do their TPACK self-confident levels reflect the technology integration levels of mathematics teachers?

- What level of technology integrates does the mathematics teachers into their classes?
- What are the mathematics teachers TPACK self-confidence levels?;
    - Do TPACK self-confidence levels of mathematics teachers differ according to their views about use of technological tools by the students?
    - Do TPACK self-confidence levels of mathematics teachers differ according to their frequency of using technological tools and the variety of these tools they use in their classes?

## RESEARCH METHOD

### Research Model

In this study, which aimed to determine the extent to which secondary education mathematics teachers integrate technology into their classes and their TPACK self-confidence levels, qualitative and quantitative data were needed. Therefore, the convergent parallel design of a mixed method was utilized in the study (Figure 1). In this design, after qualitative and quantitative data are collected and analysed simultaneously, whether the findings support each other (Fraenkel, Wallen & Hyun, 2011). In this study teachers' views, which formed the qualitative data, and the scores of the scales, which formed the quantitative data, were collected simultaneously via the same form.

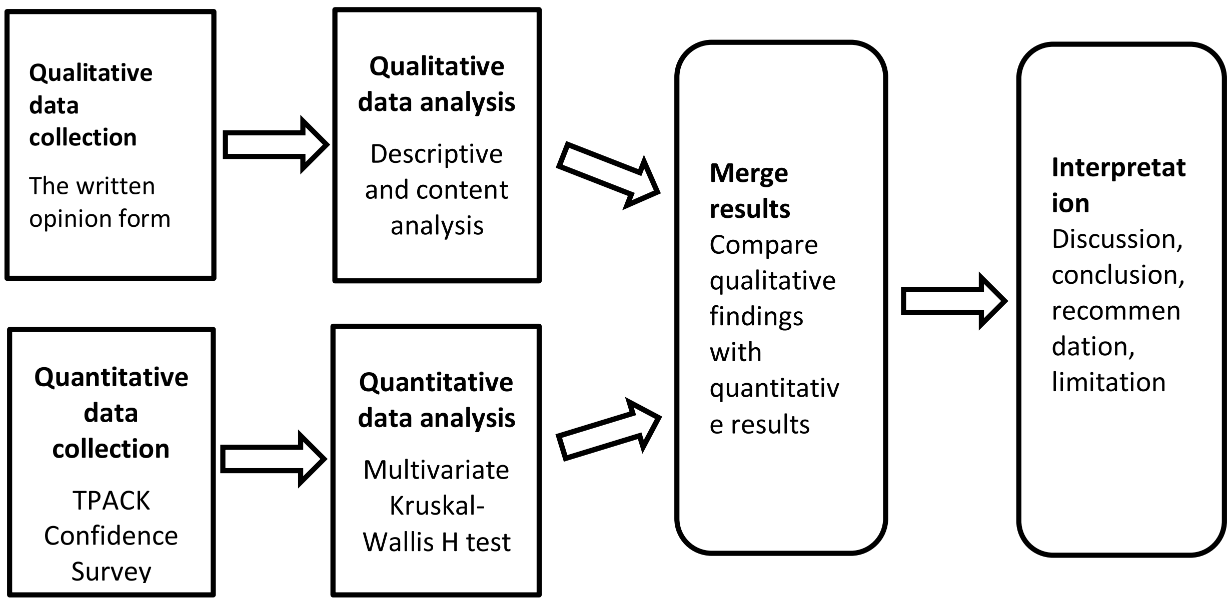


**Figure 1.** *The Research Design of the Study*

### Participants

Fifty-seven secondary mathematics teachers, 17 females and 40 males, participated in the study. The participants, who were identified on a voluntary basis using the random sampling method, work in 22 high schools of five types in Adıyaman province in southeastern Turkey. Convenience samples are relatively inexpensive and practical and easy for some researchers. In a random sample, a population is selected based on its convenient accessibility and proximity (Yıldırım & Şimşek, 2008). Table 1 below shows the technical tools that the participants and their schools have.

**Table 1.** *The Technological Tools Those Teachers and Their Schools Have*

| Technological tools that teachers have | f | % |
|---|---|---|
| Smartphone | 52 | 91.2 |
| Laptop | 44 | 77.2 |
| Tablet Computer | 43 | 75.4 |
| Desktop Computer | 21 | 36.8 |
| **Technological possibilities of the schools' teachers work** | **f** | **%** |
| Smartboard (in the classroom) | 53 | 93 |
| Desktop Computer (in the Classroom) | 39 | 68.4 |
| Tablet Computer in Students | 12 | 21.1 |
| Projector | 8 | 14 |
| Technology Classroom | 5 | 8.8 |

**Data Collection and Data Analysis**

In the study, a form consisting of three parts was used as a data collection tool. The first part of the form contains questions about the demographic characteristics of the participants and about the technological facilities that they and their schools have. The second part of the form was a written opinion form that aimed to receive the teachers' views about to what extent they integrate technology into their classes. And the final part of the form contained "Technological Pedagogical Content Knowledge Confidence Survey" (TPACK CS).

The written opinion questionnaire contained a series of semi-structured and open-ended questions to determine how mathematics teachers benefit from technological tools and what kind of hardware and software they use in their teaching. The written opinion questionnaire was constructed using semi-structured interview forms developed by the researcher in previous studies (Ardıç & İşleyen, 2017b; 2017c), and "Technology Integration Tracking Form" (Ardıç & İşleyen, 2017a). In creating the relevant forms, the literature on technology integration in teaching-learning environments was first reviewed and initial drafts were created using resources with information on scientific research methods. Later, the opinions of four experts holding doctoral degrees in mathematics education were sought on the preliminary drafts and draft forms were created. Subsequently, pilot implementations were carried out to ensure the validity of the mentioned draft forms and to address any shortcomings. During the pilot implementation, the draft opinion forms were given to 11 mathematics teachers who used technological aids. In addition, three mathematics teachers were observed during their technology integration activities for 20 lessons. Necessary changes were made to the drafts based on the findings and opinions of a mathematics educator and three mathematics teachers. Thus, the forms received their final versions.

One of the questions in the written opinion form is as follows: How do you use technological aids in your teaching?

The "descriptive analysis" and "content analysis" methods were used to analyse the qualitative data obtained in the study. The researcher then transcribed the views of the participating secondary mathematics teachers. Data were summarized and interpreted primarily using descriptive analysis. Content analysis was then conducted to identify the concepts and codes not identified in the initial analysis. In the content analysis, the teachers' views were first analysed individually. Then, each teacher's response to each question was examined to create codes, categories, and frequencies for each question. Then, the researcher reviewed each participant's data to gain insight into their holistic approach to the topic at hand. Once related categories sorted the codes obtained, they were grouped according to the themes identified by the research questions. The frequencies used to determine how many participants held the same views were represented by the letter "f" in the corresponding tables. To determine the extent to which participating teachers integrated technology into their teaching when analysing their views, the items developed by the Ardıç and İşleyen (2017a) were used in the "Technology Integration Tracking Form". To achieve "internal reliability" and "validity" in the study, it was ensured that the data collected and analysed from the written opinion forms were consistent both internally and concerning the theoretical framework. In doing so, the researcher took into consideration how an outsider would understand the study. In order to achieve "external validity" and "verifiability" of the study, the raw data obtained and conclusions drawn during the study were comparatively analysed and later subjected to expert analysis. The findings and conclusions of the study were determined in consultation with the relevant experts who hold doctoral degrees in mathematics education. Excerpts from the written opinion forms were also included to explain the codes and the level of technology integration. In addition, all data collection instruments used in the study and the data obtained were stored on electronic media for reuse as needed.

The original version of TPACK CS used in the research was developed by Graham, Burgoyne, Cantell, Smith, and Harris (2009). The scale was then adapted to Turkish and applied to science and technology teachers by Timur and Taşar (2011), who also conducted the factor analysis and reliability studies. The final Turkish version of the scale contains 31 five-point Likert-type questions. The scale consists of four dimensions. These dimensions and their "Cronbach's Alpha reliability coefficients" are .89 for the TPACK dimension, .87 for the TPK dimension, and .86 for the TCK dimension. In addition, the overall "Cronbach's

Alpha reliability coefficient" of the scale was calculated to be .92 and it was decided that TPACK CS could also be used in Turkey. The scale was then adapted to different domains, including mathematics, and used in different studies in Turkey. Considering that mathematics teachers would be participants in the study, the version of TPACK CS with a "Cronbach's Alpha reliability coefficient" of .93 was used, which was created by Önal and Çakır (2015) to adapt to different fields of study. In addition, the "Cronbach's Alpha reliability coefficient" of the total scale was calculated as .96 in this study.

In this study "Multivariate Kruskal-Wallis H test" (MKW) was used to examine the quantitative data obtained from TPACK CS. At the each step of the analysis the data to be examined were checked for compliance with the assumptions of the multivariate linear model (normality, multivariate normality, homogeneity of covariance matrices). However it's understood that the multivariate normality assumption violated. When this assumption is violated, the non-parametric MKW test is frequently used (He at al., 2018). In studies MKW is applied for each dependent variable to determine the source of the differences observed in the dependent variables. To prevent the familywise error in the evaluation of repeated MKWs the "Bonferroni correction" was used and the value of .05 significance level was divided by the number of tests (or dependent variables) to determine the level of new significance. Thus the significance level of the study was calculated as "$\alpha$ =.01". On the other hand, post hoc tests were performed to determine between which independent variables the significant differences, which were observed in the dependent variables as a result of the MKWs performed, emerged. In this study "Dunn-Bonferroni post hoc method" which has "Bonferroni adjustment" was used. The "Bonferroni adjustment" the multiplication of each estimated p-value by the number of comparisons performed (Gignac, 2019). For this study the adjusted p values (p') less than .01 is statistically significant.

Mathematics teachers' scores from the whole TPACK CS and the sub-dimensions of the TPACK were divided by the number of items in the relevant scale to obtain the means. Thus, the scores were made suitable for 5-point rating. The confidence level of the teachers was determined by taking into consideration the interval range in Table 2.

**Table 2.** *Confidence Range for the TPACK CS*

| Interval Range | Confidence Level |
|---|---|
| 1.00 - 1.79 | "Not confident at all" |
| 1.80 - 2.59 | "Slightly confident" |
| 2.60 - 3.39 | "Somewhat confident" |
| 3.40 - 4.19 | "Fairly confident" |
| 4.20 - 5.00 | "Completely confident" |

## FINDINGS

Findings obtained from views of secondary mathematics teachers in the questionnaires and TPACK CS, are presented in the form of sub-problems.

### What Level of Technology Integrates Does The Mathematics Teachers into Their Classes?

The researcher analysed the views of secondary mathematics teachers in the questionnaires. The obtained technology integration levels of the participant teachers resulting from the analysis are presented in Table 3.

**Table 3.** *Technology Integration Levels of Teachers*

| Technology Integration Levels | f (%) |
|---|---|
| 0. Level: None use of technology | 8 (14) |
| 1. Level: Replacement | 45 (78.9) |
| 2. Level: Amplification | 4 (7) |
| 3. Level: Transformation | - |

When the questionnaires were being analysed, the cases where the technological equipment only provided a change in the educational environment and was not used for different objectives or achievements were considered as the "replacement level". It is seen that the majority of the mathematics teachers (45 teachers) integrated technology into their classes at the "replacement level". Some mathematics teachers stated that they use technological tools (especially smartboards) to display lecture notes and solve lots of sample problems. Some of their views are as follows:

*"By using a smartboard in my classes, I display lecture notes on it and solve lots of problems in a short time."*

*"I use technological tools to easily show my presentations to the whole class."*

*"Writing things on a blackboard makes me lose time. On the other hand, since mathematical problems are already loaded in the smartboard, students both solve more problems and they can more easily understand some geometric shapes. "*

In the analysis of the questionnaires, the levels of technology integration, where teachers aimed at effective and fast learning with the use of technological tools, but did not make a radical change in their usual teaching style, were considered as "amplification level". It was found that only four of the teachers integrated technology into their teaching at the "amplification level", which is the middle level. These teachers indicated that they send questions to their students and receive feedback from them through tablet computers or use GeoGebra, a dynamic geometry software, in their teaching. Some of their views are as follows:

*"I use tablets for sending questions to students, assigning homework, analysing test results, preparing lesson contents, and so on."*

*"For effective lessons, I use animations and the materials that I prepare using GeoGebra. But, usually, I use PDF documents to prepare problems for the students. Because 12th graders (students at the last grade of high school) prepare for the exam (university entrance exam). "*

**What Are The Mathematics Teachers TPACK Self-Confidence Levels?**

As a result of the descriptive analysis, it is seen that the mathematics teachers' overall mean of TPACK CS is M = 3.577 and they have a moderate level of self-confidence, i.e., they are somewhat confident (Table 4). When the sub-dimensions of the scale are examined, it is seen that the participant teachers have a moderate level of self-confidence in TPACK, TCK and TK dimensions. Also, it is seen that with a mean of M = 3.551, TPK is the sub-dimension where the teachers have the most self-confidence.

**Table 4.** *TPACK self-confidence levels of teachers*

| | N | M | SD | Confidence Level |
|---|---|---|---|---|
| **TPACK** | 57 | 3.377 | .702 | Somewhat confident |
| **TPK** | 57 | 3.551 | .748 | Fairly confident |
| **TCK** | 57 | 3.231 | 1.019 | Somewhat confident |
| **TK** | 57 | 3.269 | .935 | Somewhat confident |
| **TPACK CS** | 57 | 3.354 | .745 | Somewhat confident |

The TPACK self-confidence means of mathematics teachers and MKW statistics, according to their levels of technology integration are shown in Table 5. As a result of the analysis, it was found that there was no significant difference in TPACK self-confidence of secondary mathematics teachers in terms of TPACK components according to their technology integration levels (p>.01).

**Table 5.** *TPACK CS Scores and MKW Results by Technology Integration Levels of Teachers'*

| TPACK Components | Integration Level | N | M | SD | M Rank | df | H | p* | η2 |
|---|---|---|---|---|---|---|---|---|---|
| **TPACK** | None | 8 (%14) | 3.203 | .530 | 24.19 | 2 | 2.653 | .265 | .047 |
| | Replacement | 45 (%78) | 3.364 | .722 | 28.82 | | | | |
| | Amplification | 4 (%7) | 3.875 | .699 | 40.63 | | | | |
| **TPK** | None | 8 (%14) | 3.321 | .825 | 23.63 | 2 | 1.288 | .525 | .023 |
| | Replacement | 45 (%78) | 3.571 | .734 | 29.49 | | | | |
| | Amplification | 4 (%7) | 3.785 | .853 | 34.25 | | | | |
| **TCK** | None | 8 (%14) | 3.125 | .973 | 26.94 | 2 | 1.755 | .416 | .031 |
| | Replacement | 45 (%78) | 3.195 | 1.050 | 28.44 | | | | |
| | Amplification | 4 (%7) | 3.850 | .660 | 39.38 | | | | |
| **TK** | None | 8 (%14) | 2.852 | .504 | 19.13 | 2 | 5.681 | .058 | .101 |
| | Replacement | 45 (%78) | 3.274 | .971 | 29.52 | | | | |
| | Amplification | 4 (%7) | 4.045 | .794 | 42.88 | | | | |
| **TPACK CS** | None | 8 (%14) | 3.092 | .522 | 21.63 | 2 | 3.903 | .142 | .070 |
| | Replacement | 45 (%78) | 3.352 | .769 | 29.19 | | | | |
| | Amplification | 4 (%7) | 3.911 | .672 | 41.63 | | | | |

*α =.01

On the other hand, the analysis of the questionnaires showed that none of the mathematics teachers integrated technology into the classroom at the level of "transformation"; none deviated from their usual teaching practice and none placed the student at the center of the educational process, allowing him to realize deep learning through interaction with technological tools.

***Do TPACK self-confidence levels of mathematics teachers differ according to their views about use of technological tools by the students?***

It was understood that the majority of mathematics teachers (59.6%) did not favor students using technological tools in lessons. On the other hand, some of the teachers (26.3%) favored it while others were undecided (14%). TPACK self-confidence means of secondary mathematics teachers according to their views on whether students should use technological tools in classes are shown in Table 6.

**Table 6.** *TPACK CS Scores and MKW Results by Teachers' Views on Students' Use Technological Tools in Classes*

| TPACK Components | Views | N | M | SD | M Rank | df | H | p* | η2 | Post Hoc |
|---|---|---|---|---|---|---|---|---|---|---|
| **TPACK** | 0. Not favor | 34 (%59.6) | 3.147 | .670 | 23.35 | 2 | 10.035 | .007 | .179 | 2>0 |
| | 1. Undecided | 8 (%14) | 3.562 | .563 | 35.06 | | | | | |
| | 2. Favor | 15 (%26.3) | 3.80 | .645 | 38.57 | | | | | |
| **TPK** | 0. Not favor | 34 (%59.6) | 3.437 | .850 | 27.07 | 2 | 1.157 | .561 | .021 | |
| | 1. Undecided | 8 (%14) | 3.696 | .510 | 31.31 | | | | | |
| | 2. Favor | 15 (%26.3) | 3.733 | .573 | 32.13 | | | | | |
| **TCK** | 0. Not favor | 34 (%59.6) | 2.976 | 1.085 | 24.22 | 2 | 7.571 | .023 | .135 | |
| | 1. Undecided | 8 (%14) | 3.350 | 1.125 | 32.69 | | | | | |
| | 2. Favor | 15 (%26.3) | 3.746 | .542 | 37.87 | | | | | |
| **TK** | 0. Not favor | 34 (%59.6) | 3.064 | .986 | 25.72 | 2 | 3.553 | .169 | .063 | |
| | 1. Undecided | 8 (%14) | 3.660 | .620 | 36.25 | | | | | |
| | 2. Favor | 15 (%26.3) | 3.527 | .868 | 32.57 | | | | | |
| **TPACK CS** | 0. Not favor | 34 (%59.6) | 3.155 | .787 | 24.44 | 2 | 6.423 | .040 | .115 | |
| | 1. Undecided | 8 (%14) | 3.592 | .540 | 34.56 | | | | | |
| | 2. Favor | 15 (%26.3) | 3.680 | .611 | 36.37 | | | | | |

*α =.01

MKWs results indicate that there is a significant difference in the TPACK component. (H(2)=10.035, p<.01, η2 =.179). Also, the post hoc test revealed that there is a significant difference in the TPACK component between the teachers who favored students using technological tools in classes and who did not favor it. As a result, a significant difference was found in the TPACK component in favor of the teachers who favored students using technological tools in their classes (p’<.01).

It was understood that the majority of the mathematics teachers (65%) favored students using technological tools for studying or doing homework outside the classroom (at home, etc.). On the other hand, some of the teachers (35%) did not favor it. TPACK self-confidence means of secondary mathematics teachers according to their views on whether students should use technological tools for studying outside the classroom are shown in Table 7.

**Table 7.** *TPACK CS Scores and MKW Results by Teachers’ Views on Students’ Use Technological Tools Outside the Classes*

| TPACK Components | Views | N | M | SD | M Rank | df | H | p* | η2 |
|---|---|---|---|---|---|---|---|---|---|
| **TPACK** | Not favor | 20 (%35) | 3.243 | .164 | 26.35 | 1 | .789 | .374 | .014 |
| | Favor | 37 (%65) | 3.449 | .112 | 30.43 | | | | |
| **TPK** | Not favor | 20 (%35) | 3.421 | .190 | 27.30 | 1 | .326 | .568 | .006 |
| | Favor | 37 (%65) | 3.621 | .113 | 29.92 | | | | |
| **TCK** | Not favor | 20 (%35) | 3.250 | .207 | 28.33 | 1 | .051 | .821 | .001 |
| | Favor | 37 (%65) | 3.221 | .177 | 29.36 | | | | |
| **TK** | Not favor | 20 (%35) | 3.013 | .210 | 24.70 | 1 | 2.072 | .150 | .037 |
| | Favor | 37 (%65) | 3.407 | .150 | 31.32 | | | | |
| **TPACK CS** | Not favor | 20 (%35) | 3.203 | .180 | 26.20 | 1 | .878 | .349 | .016 |
| | Favor | 37 (%65) | 3.436 | .116 | 30.51 | | | | |

*α =.01

The MKW tests conducted revealed that teachers' TPACK confidence did not show significant differences in relation to the TPACK components depending on whether they believed that students should use technological tools outside the classroom to prepare for their lessons (Table 21).

***Do TPACK self-confidence levels of mathematics teachers differ according to their frequency of using technological tools and the variety of these tools they use in their classes?***

It was understood that the majority of the teachers used technological tools in almost all of their classes (49.1%) or in some classes during the week (15.8%). However, it was also seen that a significant number of teachers very rarely (15.8%) or never (14%) use technological tools. TPACK self-confidence means of mathematics teachers according to their frequency of using technological tools in their classes are shown in Table 8.

According to MKW tests performed, it was found that TPACK self-confidence of teachers did not show significant differences in terms of TPACK components according to their frequency of using technological tools in their classes (p>.01).

**Table 8.** *TPACK CS Scores and MKW Results by Teachers' Frequency of Using Technological Tools*

| TPACK Components | Frequency of Using | N | M | SD | M Rank | df | H | p* | η2 |
|---|---|---|---|---|---|---|---|---|---|
| **TPACK** | Never | 8 (%14.0) | 3.203 | .530 | 24.19 | 4 | 3.022 | .554 | .054 |
| | Almost all of classes | 28 (%49.1) | 3.317 | .826 | 27.57 | | | | |
| | Some classes during the week | 9 (%15.8) | 3.694 | .596 | 36.83 | | | | |
| | Some classes during the month | 9 (%15.8) | 3.430 | .488 | 30.56 | | | | |
| | Very rarely in certain subjects | 3 (%5.3) | 3.291 | .763 | 27.00 | | | | |
| **TPK** | Never | 8 (%14.0) | 3.321 | .825 | 23.63 | 4 | 3.300 | .509 | .059 |
| | Almost all of classes | 28 (%49.1) | 3.495 | .735 | 28.32 | | | | |
| | Some classes during the week | 9 (%15.8) | 3.968 | .601 | 37.39 | | | | |
| | Some classes during the month | 9 (%15.8) | 3.539 | .807 | 28.39 | | | | |
| | Very rarely in certain subjects | 3 (%5.3) | 3.476 | .951 | 26.33 | | | | |
| **TCK** | Never | 8 (%14.0) | 3.125 | .973 | 26.94 | 4 | 5.284 | .259 | .094 |
| | Almost all of classes | 28 (%49.1) | 3.078 | 1.044 | 26.38 | | | | |
| | Some classes during the week | 9 (%15.8) | 3.733 | .748 | 37.06 | | | | |
| | Some classes during the month | 9 (%15.8) | 3.600 | .800 | 34.56 | | | | |
| | Very rarely in certain subjects | 3 (%5.3) | 2.333 | 1.701 | 18.17 | | | | |
| **TK** | Never | 8 (%14.0) | 2.852 | .504 | 19.13 | 4 | 5.788 | .216 | .103 |
| | Almost all of classes | 28 (%49.1) | 3.246 | 1.048 | 29.54 | | | | |
| | Some classes during the week | 9 (%15.8) | 3.818 | .870 | 38.22 | | | | |
| | Some classes during the month | 9 (%15.8) | 3.171 | .861 | 27.89 | | | | |
| | Very rarely in certain subjects | 3 (%5.3) | 3.242 | .814 | 26.00 | | | | |
| **TPACK CS** | Never | 8 (%14.0) | 3.092 | .522 | 21.63 | 4 | 5.953 | .203 | .106 |
| | Almost all of classes | 28 (%49.1) | 3.293 | .822 | 27.98 | | | | |
| | Some classes during the week | 9 (%15.8) | 3.806 | .590 | 39.89 | | | | |
| | Some classes during the month | 9 (%15.8) | 3.390 | .695 | 29.78 | | | | |
| | Very rarely in certain subjects | 3 (%5.3) | 3.161 | .923 | 23.17 | | | | |

*α =.01

Additionally it was seen that the majority of mathematics teachers (80.7%) use smartboards in their classes. It was also understood that some of the teachers used more than one technological tool in their classes (Table 9).

**Table 9.** *The Technological Tools Teachers' Use in Their Classes*

| Technological tools | *f (%)* |
|---|---|
| Smartboard | 46 (80,7) |
| Tablet Computer | 9 (15,8) |
| Computer | 6 (10,5) |
| Projection | 1 (1,8) |
| Smartphone | 1 (1,8) |

TPACK self-confidence means of mathematics teachers according to the variety of technological tools that they use in their classes are shown in Table 10.

**Table 10.** *TPACK CS Scores and MKW Results by Technological Tools Teachers' Use in Their Classes*

| TPACK Components | Views | N | M | SD | M Rank | df | H | p* | η2 |
|---|---|---|---|---|---|---|---|---|---|
| **TPACK** | None | 8 (%14) | 3.203 | .530 | 24.19 | 2 | 3.063 | .216 | .055 |
| | Only smartboard | 35 (%61.4) | 3.296 | .697 | 27.53 | | | | |
| | Multiple tools | 14 (%24.5) | 3.678 | .752 | 35.43 | | | | |
| **TPK** | None | 8 (%14) | 3.321 | .825 | 23.63 | 2 | 3.895 | .143 | .070 |
| | Only smartboard | 35 (%61.4) | 3.465 | .723 | 27.33 | | | | |
| | Multiple tools | 14 (%24.5) | 3.898 | .703 | 36.25 | | | | |
| **TCK** | None | 8 (%14) | 3.125 | .973 | 26.94 | 2 | 5.584 | .061 | .100 |
| | Only smartboard | 35 (%61.4) | 3.040 | 1.053 | 25.86 | | | | |
| | Multiple tools | 14 (%24.5) | 3.771 | .800 | 38.04 | | | | |
| **TK** | None | 8 (%14) | 2.852 | .504 | 19.13 | 2 | 5.396 | .067 | .096 |
| | Only smartboard | 35 (%61.4) | 3.181 | .954 | 28.44 | | | | |
| | Multiple tools | 14 (%24.5) | 3.727 | .948 | 36.04 | | | | |
| **TPACK CS** | None | 8 (%14) | 3.092 | .522 | 21.63 | 2 | 6.489 | .039 | .116 |
| | Only smartboard | 35 (%61.4) | 3.252 | .750 | 26.97 | | | | |
| | Multiple tools | 14 (%24.5) | 3.760 | .726 | 38.29 | | | | |

*α =.01

As a result of MKW tests, it was found that TPACK self-confidence levels of secondary mathematics teachers did not show significant differences according to the variety of technological tools they use in their classes (p>.01).

It was observed that mathematics teachers mostly used presentation software such as PDF reader (68.4%) and Microsoft PowerPoint (47.4%) that are used to present lecture notes and word processors such as Microsoft Word (31.6%) (Table 11). It was also seen that a very small number of teachers used GeoGebra (3.5%), a dynamic geometry software (DGS) used in mathematics teaching, or Mathematica (1.7%), a computer algebra system (CAS).

**Table 11.** The Software That Teachers' Use in Their Classes

| Software | f (%) |
|---|---|
| PDF reader | 39 (68.4) |
| Presentation software | 27 (47.4) |
| Word processors | 18 (31.6) |
| Multimedia player | 14 (24.4) |
| GeoGebra | 2 (3.5) |
| Mathematica | 1 (1.7) |
| Others | 2 (3.5) |

While some mathematics teachers (28%) used only one computer software in their classes, some (58%) used more than one computer software. TPACK self-confidence means of teachers according to the variety of computer software that they use in their classes are shown in Table 12.

**Table 12.** *TPACK CS Scores and MKW Results by Software That Teachers' Use in Their Classes*

| TPACK Components | Views | N | M | SD | M Rank | df | H | p* | η2 | Post Hoc |
|---|---|---|---|---|---|---|---|---|---|---|
| **TPACK** | 0. None | 8 (%14) | 3.203 | .530 | 24.19 | 2 | 11.400 | .003 | .204 | 2>1 |
| | 1. Only one software | 16 (%28) | 2.930 | .635 | 18.72 | | | | | |
| | 2. More than one software | 33 (%58) | 3.636 | .659 | 35.15 | | | | | |
| **TPK** | 0. None | 8 (%14) | 3.321 | .825 | 23.63 | 2 | 9.678 | .008 | .173 | 2>1 |
| | 1. Only one software | 16 (%28) | 3.090 | .782 | 19.88 | | | | | |
| | 2. More than one software | 33 (%58) | 3.831 | .586 | 34.73 | | | | | |
| **TCK** | 0. None | 8 (%14) | 3.125 | .973 | 26.94 | 2 | 10.142 | .006 | .181 | 2>1 |
| | 1. Only one software | 16 (%28) | 2.575 | 1.092 | 18.63 | | | | | |
| | 2. More than one software | 33 (%58) | 3.575 | .842 | 34.53 | | | | | |
| **TK** | 0. None | 8 (%14) | 2.852 | .504 | 19.13 | 2 | 17.315 | .000 | .309 | 2>1 |
| | 1. Only one software | 16 (%28) | 2.568 | .996 | 17.88 | | | | | |
| | 2. More than one software | 33 (%58) | 3.710 | .721 | 36.79 | | | | | |
| **TPACK CS** | 0. None | 8 (%14) | 3.092 | .522 | 21.63 | 2 | 17.826 | .000 | .318 | 2>1 |
| | 1. Only one software | 16 (%28) | 2.780 | .733 | 16.59 | | | | | |
| | 2. More than one software | 33 (%58) | 3.697 | .598 | 36.80 | | | | | |

*α =.01

The analysis revealed that secondary mathematics teachers' TPACK confidence varies significantly depending on the variety of software they use in their classrooms. Looking at the statistics in Table 12, this difference is evident across the TPACK CS ($H(2)=17.826$, $p<.001$, $\eta^2=.318$) and across all TPACK components. A post- hoc test was conducted to determine between which groups this difference existed. In all components, significant differences were found between teachers who used only one computer software and teachers who used more than one computer software in favor of those who used more than one computer software (p' <.01).

## DISCUSSION AND CONCLUSION

When the views of mathematics teachers are examined, it is found that a significant proportion of them rarely or never use technological aids in their teaching. It was also found that very few teachers integrate technology in their teaching at the amplification level, which we can consider as the middle level. Moreover, none of the teachers integrated technology into their teaching at the transformational level to change the classroom environment. This result is consistent with the level of technology integration of mathematics teachers before the in-service training on computer-assisted mathematics education conducted by the Ardıç and İşleyen (2017a). Similarly, some international studies found that the use of technology in mathematics education only replaced traditional methods and tools (Bray & Tangney, 2017; Egan, FitzGibbon & Oldham, 2013; Ottenbreit-Leftwich et al., 2012; Thinyane, 2010), while some others placed the level of technology integration at the intermediate level (Bray & Tangney, 2017; Pimm & Johnston-Wilder, 2005; Psycharis, Chalatzoglidis & Kalogiannakis, 2013).

Looking at the mean scores of TPACK CS and the mean scores of TPACK, TCK and TK components of mathematics teachers, we find that they have moderate self-confidence. This result is consistent with the result reported by Karataş and Aslan-Tutak (2017) in their study with secondary mathematics teachers. However, this result also contradicts the findings of many studies (Saltan & Arslan, 2017) that investigated teachers and prospective teachers of different disciplines and found that these teachers have high levels of self-confidence (Açıkguel & Aslaner, 2015; Bozkurt, 2016; Koeseoğlu, 2012; Sancar Tokmak, Yavuz Konukman & Yanpar Yelken, 2013; Tuysuz, 2014). The fact that teachers have only moderate TPACK confidence largely explains why they fail to integrate technology into their teaching at the desired level. Indeed, the fact that mathematics teachers' TPACK confidence does not differ according to their level of technology integration points to this situation. Similarly, Karataş and Aslan-Tutak (2017) concluded that mathematics teachers with moderate levels of TPACK also have moderate levels of technology integration self-efficacy, which is consistent with this conclusion. Furthermore, Hill and Uribe-Florez (2020) concluded that teachers' TPACK is reflected in the strategies they use to integrate technology in the classroom. Consequently, it can be said that mathematics teachers' level of technology integration is reflected in their TPACK self-confidence.

Similarly, the frequency with which teachers use technological aids in their teaching. It was found that majority of the teachers frequently use technological aids in their teaching. However, the results of the analyses also indicate that teachers' TPACK confidence, like technology integration, does not differ according to the frequency of using technological aids in their teaching. This result was obtained despite the fact that a significant number of teachers rarely or never use technological aids in their teaching. The low level of technology integration and TPACK confidence of mathematics teachers (despite the fact that they frequently use technological aids in their teaching) is a remarkable result. This could be due to their lack of knowledge about the technical features of the technological aids they can use in their classrooms (i.e. TK) and what hardware, software and level of integration are required for teaching a particular subject (i.e. TCK).

The study also found that the majority of mathematics teachers either do not support the use of technological aids by the students in the classroom or are undecided on the issue. On the other hand, most of the teachers favour students using technological aids outside the classroom to prepare for lessons. This change in teachers' views is also reflected in teachers' TPACK confidence. While there is no significant difference in teachers' TPACK self-confidence regarding whether students should use technological tools to prepare for class, there is a significant difference among those who support the use of technological tools in the classroom. The significant difference observed, especially in the TPACK component, suggests that this situation may be because teachers do not have sufficient knowledge about the possibilities and limitations of the technologies to be used in the classroom. This result is consistent with the findings of the studies that mathematics teachers who have received in-service training on the use of technology in the classroom have higher levels of TPACK (Karataş & Aslan-Tutak, 2017), have positively changed their views on students' use of technological tools in the classroom (Ardıç & İşleyen, 2017c), and have integrated technology into their teaching at a higher level (Ardıç & İşleyen, 2017a).

When examining the views of mathematics teachers who indicated that they benefit from technological aids in their teaching, it is clear that many of them only use smartboards. It is also evident that the majority of teachers integrate technology into their teaching at the replacement level. These two things taken together suggest that the way teachers use smartboards in their teaching is not significantly different from the way they used computers and projectors in the past. Indeed, if we look at the technological tools that teachers use in their teaching, we can see that they use either a computer (PC, Tablet PC, Smartboard, SmartPhone) or a display device (Smartboard, Projector). This could be the reason why mathematics teachers' TPACK confidence does not differ according to the variety of technological tools they use in their teaching. On the other hand, teachers' TPACK confidence varies according to the variety of computer software they use. It was found that the TPACK self-confidence of teachers who use more than one computer software in their teaching is significantly higher than that of teachers who do not, and that the teachers who integrate technology in their teaching to a higher extent also use BCS and DGS. This suggests that the computer software used by teachers is more critical to the level of technology integration than the variety of technology tools used. Previous studies have also reported that secondary mathematics teachers who use software such as BCS in their teaching integrate technology into their teaching at a higher level (Ardıç & İşleyen, 2017a). Similarly, learning environments using dynamic mathematics software were found to contribute to increasing prospective teachers' TPACK confidence (Atasoy, Uzun & Ayguen, 2015).

A significant number of the findings obtained in the research differs from the findings of many studies, the participants of which were prospective teachers. Even this situation differs from the findings of Saltan and Aslan (2017), who stated that there is no difference between the TPACK self-confidence levels of teachers and prospective teachers in terms of TPACK self-confidence. There may be two reasons for this. First, it may be because the prospective teachers who participated in these studies do not yet have enough professional experience. Another reason may be that most of the studies investigated the TPACK self-confidence levels of the participants by only considering their general technological knowledge. That is, this may be due to the lack of consideration of particular classroom practice in the teaching of any field or technology for the training of the field.

### Recommendations

When the significant differences and effect sizes observed in the research are considered as a whole, the components of TPACK and TK come to the fore. This implies that it is important for mathematics teachers to be able to identify and use appropriate technologies to achieve effective technology integration in the classroom. It is assumed that teachers have no difficulty in using technological devices such as computers or smartboards at a basic level. However, computer software was found to have a significant impact on teachers' confidence and level of technology integration. For this reason, instead of teaching the technical features of a technological tool, teachers could be provided with hands-on training on different technological tools where students can participate in the process during the pedagogical activities as well as the software. In this context, in-service training programs can be organized for teachers on software that has been shown to have a positive impact on high school students' mathematical achievement, such as GeoGebra (Zulnaidi, Oktavika & Hidayat, 2020) and Mathematica (Ardıç & İşleyen, 2018). In this way, it can increase the TPACK confidence of mathematics teachers and ensure that they integrate technology into their teaching at a higher level where their students can be actively involved.

The results of the study were limited to data collected from 57 mathematics teachers at 22 different high schools. Therefore, data on TPACK CS in particular were interpreted along with qualitative data and with an in-depth perspective to avoid over-generalization. Similar studies can be conducted with larger samples to obtain more generalizable results. In addition, by conducting similar studies with teachers from different disciplines, better insight into teaching practices can be gained.

## REFERENCES

Abbitt, J. T. (2011). Measuring technological pedagogical content knowledge in preservice teacher education: A review of current methods and instruments. *Journal of Research on Technology in Education*, *43*(4), 281–300.

Açıkgül, K. & Aslaner R. (2015). İlköğretim matematik öğretmen adaylarının TPAB güven algılarının incelenmesi [Investigation of TPACK confidence perception of prospective elementary mathematics teachers]. *Erzincan Üniversitesi Eğitim Fakültesi Dergisi*, *17*(1), 118-152.

Akkoç, H., Özmantar, M. F., Bingölbali, E., Demir, S., Baştürk, S., & Yavuz, İ. (2011). *Matematik öğretmen adaylarına teknolojiye yönelik pedagojik alan bilgisi kazandırma amaçlı program geliştirme* [Project development for bring mathematics teachers candidates in TPAC]. TÜBİTAK (The Scientific and Technological Research Council of Turkey) Project of Number 107K531. İstanbul, Turkey.

Ardıç, M. A., & İşleyen, T. (2017a). High school teachers' levels of achieving technology integration and in-class reflections: The case of Mathematica. *Universal Journal of Educational Research*, *5*(12B),1-17.

Ardıç, M. A., & İşleyen, T. (2017b). High school teachers' views on computer-assisted mathematics instruction through Computer Algebra Systems in Turkey. *European Journal of Education Studies*, [S.l.], mar. 2017.

Ardıç, M. A., & İşleyen, T. (2017c). Secondary school mathematics teachers' and students' views on computer assisted mathematics instruction in Turkey: Mathematica example. *Malaysian Online Journal of Educational Technology*, *5*(1), 46-64.

Ardıç, M. A., & İşleyen, T. (2018). The effect of mathematics instruction through Computer Algebra Systems on the academic achievements of secondary education students: Turkey example. *Journal of Education and e-Learning Research*, *5*(3), 165-173.

Atasoy, E., Uzun, N., & Aygün, B. (2015). Dinamik matematik yazılımları ile desteklenmis ögrenme ortamında ögretmen adaylarının teknolojik pedagojik alan bilgilerinin incelenmesi [Investigating pre-service teachers' technological pedagogical content knowledge in learning environment supported by dynamic mathematics software]. *Bartın University Journal of Faculty of Education*, *4*(2), 611.

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological review*, 84(2), 191.

Bandura, A. (1986). *Social foundations of thought and action: A Social cognitive theory*. Englewood Cliffs, NJ: Prentice Hall.

Baran, E., & Canbazoğlu Bilici, S. (2015). Teknolojik pedagojik alan bilgisi (TPAB) üzerine alanyazın incelemesi: Türkiye örneği [A review of the research on technological pedagogical content knowledge: The case of Turkey]. *Hacettepe University Journal of Education*, *30*(1), 15-32.

Bingölbali, E., Özmantar, F., Sağlam, Y., Demir, S., & Bozkurt, A. (2012). *İlköğretim öğretmenlerinin fen ve matematik alanlarında mesleki gelişim modeli ve bu modelin yaygınlaştırılması* [Professional development model for primary education teachers in science and mathematics fields]. TÜBİTAK (The Scientific and Technological Research Council of Turkey) Project of Number 108K330. Gaziantep, Turkey.

Bozkurt, N. (2016). Tarih öğretmeni adaylarının teknolojik pedagojik alan bilgisine yönelik özgüvenlerinin belirlenmesi [Determination of self-confidence for technological pedagogical content knowledge of pre-service history teacher]. *Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *13*(33), 153-167.

Bray, A., & Tangney, B. (2017). Technology usage in mathematics education research–A systematic review of recent trends. *Computers & Education*, *114*, 255-273.

Cattagni, A., & Farris, E. (2001). *Internet access in U.S. public schools and classrooms: 1994–2000 (NCES 2001–071).* U.S. Department of Education. National Center for Education Statistics.

Cerniamo, K. S., Ross, J. D., & Ertmer, P. A. (2010). *Technology Integration: A Standards-Based Approach*. In L. Ganster, M. Kerr, L. Mafrici (Eds.),Technology Integration for Meaningful Classroom Use: A Standards-Based Approach (pp. 1-27, 2.edt.). Wadsworth CENGAGE Learning.

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

De Rossi, M., & Trevisan, O. (2018). Technological pedagogical content knowledge in the literature: How TPCK is defined and implemented in initial teacher education. *Italian Journal of Educational Technology*, *26*(1),7-23.

Demir, S., & Özmantar, F. (2013). Teknoloji destekli matematik öğretiminde pedagojik prensipler [Pedagogical principles in technology-assisted mathematics instruction]. In M. Doğan, & E. Karakınık (Eds.), *Matematik eğitiminde teknoloji kullanımı* [Technological usage in mathematics education] (pp.1-26, 2th ed.). Nobel Publishing.

Dikmen, C., & Demirer, V. (2016). Türkiye'de teknolojik pedagojik alan bilgisi üzerine 2009-2013 yılları arasında yapılan çalışmalardaki eğilimler [Trends in studies on technological pedagogical content knowledge in Turkey between 2009 and 2013 years]. *Turkish Journal of Education, 5*(1), 33-46.

Egan, A., FitzGibbon, A., & Oldham, E. (2013). Teacher identified uses of technology in the classroom-an Irish cohort. In *Society for Information Technology & Teacher Education International Conference* (pp. 5034-5039). Association for the Advancement of Computing in Education (AACE).

Ertmer, P. A. (1999). Addressing first-and second-order barriers to change: Strategies for technology integration. *Educational technology research and development*, *47*(4), 47-61.

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education*, *42*(3), 255–284.

Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education*, 59, 423–435.

Fletcher, J.D., (2003). *Does this stuff work? A review of technology used to teach*. TeachKnowLogia, Knowledge Enterprise, Inc.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2011). *How to design and evaluate research in education*. McGraw-Hill Humanities Edition.

Gignac, G. E. (2019). *How2statsbook* (pp. C16.12- C.16.13, Online Edition 1). Perth, Australia: Author. Retrieved on 05 January 2021 from http://www.how2statsbook.com/

Göktas, Y., Gedik, N., & Baydas, O. (2013). Enablers and barriers to the use of ICT in primary schools in Turkey: A comparative study of 2005–2011. *Computers & Education*, 68, 211-222.

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

Groff, J., & Mouza, C. (2008). A framework for addressing challenges to classroom technology use. *AACE Journal*, 16(1), 21-46.

He, F., Mazumdar, S., Tang, G., Bhatia, T., Anderson, S. J., Dew, M. A., ... & Reynolds III, C. F. (2017). Non-parametric MANOVA approaches for non-normal multivariate outcomes with missing values. *Communications in Statistics-Theory and Methods*, *46*(14), 7188-7200.

Hill, J.E., & Uribe-Florez, L. (2020). Understanding secondary school teachers’ TPACK and technology implementation in mathematics classrooms. *International Journal of Technology in Education (IJTE)*, *3*(1), 1-13.

Hughes, J. (2005). The role of teacher knowledge and learning experiences in forming technology-integrated pedagogy. *Journal of Technology and Teacher Education*, *13*(2), 277-302.

International Society for Technology in Education, (2000). *National Educational Technology Standards (NETS) for Teachers,* Retrieved on 3 December 2013 from http://cnets.iste.org/teachers/

Kaleli Yılmaz, G. (2015). Analysis of technological pedagogical content knowledge studies in Turkey: A Meta-Synthesis Study. *Education & Science*, *40*(178), 103-122.

Karataş, F. İ., & Aslan Tutak, F. (2017). Lise matematik öğretmenlerinin teknolojik pedagojik alan bilgileri ve teknolojiyi bütünleştirme öz-yeterlilikleri [An examination of in-service secondary mathematics teachers' technological pedagogical content knowledge and their technology integration]. *Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *14*(37), 180-198.

Kaya, Z. & Kaya. O. N. (2013). Öğretmen eğitiminde Vignette tekniği ve uygulamaları [Vignette technique and its applications in teacher education]. *Education & Science*, *38*(168), 129-142.

Koehler, M. J., Mishra, P., & Yahya, K. (2007). Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy and technology. *Computers & Education*, 49(3), 740–762.

Koehler, M. J., & Mishra, P. (2008). Introducing TPCK in AACTE committee on innovation and technology (Ed.), *The Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators*, American Association of Colleges of Teacher Education and Routledge, New York.

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

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

Koehler, M. J., Mishra, P., & Yahya, K. (2004). Content, pedagogy, and technology: Testing a model of technology integration. Paper presented at the annual meeting of *the American Educational Research Association*, April 2004, San Diego.

Koseoglu, P. (2012). Hacettepe University prospective biology teachers' self-confidence in terms of technological pedagogical content. *Procedia-Social and Behavioral Sciences*, *46*, 931-934.

Ministry of National Education, (2013). *Ortaöğretim matematik dersi (9-12. sınıflar) öğretim programı* [Curriculum of secondary school mathematics lesson (9-12th classes)]. Retrieved on 20 July 2013 from http://ttkb.meb.gov.tr/program2.aspx?islem=1&kno=219.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *8*(6), 1017-1054.

Ottenbreit-Leftwich, A. T., Brush, T. A., Strycker, J., Gronseth, S., Roman, T., Abaci, S., & Plucker, J. (2012). Preparation versus practice: How do teacher education programs and practicing teachers align in their use of technology to support teaching and learning?. *Computers & Education*, *59*(2), 399-411.

Ottenbreit-Leftwich, A., Liao, J. Y. C., Sadik, O., & Ertmer, P. (2018). Evolution of teachers' technology integration knowledge, beliefs, and practices: How can we support beginning teachers use of technology?. *Journal of Research on Technology in Education*, *50*(4), 282-304.

Önal, N. ve Çakır, H. (2015). Eğitim fakültesi öğretim elemanlarının teknolojik pedagojik içerik bilgilerine ilişkin özgüven algıları [Self confidence perceptions of faculty of education academic staff on technological pedagogical content knowledge]. *HAYEF Journal of Education*, *12*(2), 117-131.

Pimm, D., & Johnston-Wilder, S. (2005). Technology, mathematics and secondary schools: A brief UK historical perspective. In S. Johnston-Wilder, & D. Pimm (Eds.), *Teaching secondary mathematics with ICT* (pp. 3-17).

Psycharis, S., Chalatzoglidis, G., & Kalogiannakis, M. (2013). Moodle as a learning environment in promoting conceptual understanding for secondary school students. *Eurasia Journal of Mathematics, Science&Technology Education, 9*(1), 11-21.

Saltan, F., & Arslan, K. (2017). A comparison of in-service and pre-service teachers' technological pedagogical content knowledge self-confidence. *Cogent Education*, *4*(1), 1311501.

Sancar Tokmak, H., Yavuz Konokman, G., & Yanpar Yelken, T. (2013). Mersin Üniversitesi okul öncesi öğretmen adaylarının teknolojik pedagojik alan bilgisi (TPAB) özgüven algılarının incelenmesi [An investigation of Mersin University early childhood pre-service teachers' self-confidence about their technological pedagogical content knowledge (TPACK)]. *Journal of Kirsehir Education Faculty*, *14*(1), 35-51.

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

Thinyane, H. (2010). Are digital natives a world-wide phenomenon? An investigation into South Africanfirst year students' use and experience with technology. *Computers & Education*, *55*(1), 406-414.

Timur, B. & Taşar, M.F. (2011). Teknolojik pedagojik alan bilgisi öz güven ölçeğinin (TPABÖGÖ) Türkçe'ye uyarlanması [The adaptation of the technological pedagogical content knowledge confidence survey into Turkish]. *Gaziantep Üniversitesi Sosyal Bilimleri Dergisi*, *10*(2), 839-856.

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

Tuysuz, C. (2014). Determination of pre-service teachers' self-confidence levels towards technology subdimension of technological pedagogical content knowledge. *International Journal of Academic Research*, *6*(1), 34-41.

Voogt, J., Fisser, P., Pareja-Roblin, N., Tondeur, J. & Braak, J. (2013). Technological pedagogical content knowledge: A review of the literature. *Journal of Computer Assisted Learning*, 29, 109-121.

Wu, Y. T. (2013). Research trends in technological pedagogical content knowledge (TPACK) research: A review of empirical studies published in selected journals from 2002 to 2011. *British Journal of Educational Technology*, *44*(3), 73-76.

Yıldırım, A., & Şimşek, H. (2008). *Sosyal bilimlerde nitel araştırma yöntemleri* [Qualitative research methods in social sciences] (7th ed.). Seçkin Publishing.

Zulnaidi, H., Oktavika, E., & Hidayat, R. (2020). Effect of use of GeoGebra on achievement of high school mathematics students. *Education and Information Technologies*, *25*(1), 51-72.