International Journal of Educational Studies in Mathematics

IJESIM

EDUGARDEN

# Developing an Observation Form to Determine the TPACK Usage[1]

**Rabia Gül Kırıkçılar[2], Avni Yıldız[3]**

[2] *Marmara University, Institute of Educational Sciences, Department of Mathematics Education, İstanbul, Turkey*

[3] *Zonguldak Bulent Ecevit University, Ereğli Faculty of Education, Department of Mathematics Education, Zonguldak, Turkey*

**ABSTRACT**

By the help of the recent studies on student-centered teaching, students have now begun to shift from memorizing to the structuring the knowledge. The researches mention that learning requires active, continuous and effective use of information. It is stated that people who can easily reach the information needed in the solution of any problem and who can add new ones to them are the people who achieve lifelong learning. One of the tasks for teachers is to show students how to achieve lifelong learning and especially how knowledge can be used in every aspect of life. There are several studies indicate that this information will be obtained more easily by integrating technology into education. Although there are observation forms that reveal the activities of teachers in the preparation of lesson activities, there are no ones measuring the Technological Pedagogical Content Knowledge in the course preparation processes. To the purpose of this study is to develop a valid, reliable and useful observation form for determining TPACK usage in secondary school mathematics teachers' dynamic software GeoGebra. In this study, the observation form was developed in 3 stages, namely research, pilot study, and evaluation. After the pilot study was completed, expert opinions were taken and the theoretical form was utilized. Lawshe technique was used to determine the content validity ratio. In addition, the teachers showed some behaviors not found in the observation form. These new behaviors have been evaluated and revised by the experts and finalized with the studies for the content validity.

**ARTICLE INFO**

***Article History:***
Received: 03.10.2019
Received in revised form: 13.11.2019
Accepted: 21.11.2019
Available online: 26.12.2019

***Article Type:*** Standard paper

***Keywords:*** TPACK, mathematics teachers, observation form, GeoGebra dynamic software



## 1. Introduction

Recently, it might be proposed that the transition from teacher-centered teaching to student-centered teaching has changed the role of information from memorizing to structuring. In this context, it is useful that teachers show students how to reinforce their knowledge, how to use the information they learn and how to produce new knowledge (Açıkgöz, 2005). For this purpose, it is necessary to use some technologies to enrich the learning environment and taking into account the changes in the educational environment with increasing demand for technology in education. Moreover, in recent years, it has been emphasized by many researchers that teachers should have a concrete understanding of the content of the subject (Joo, Park and Lim, 2018). Mere technology cannot improve teaching and learning, use of technology should, above all, be designed to support learning objectives (Ertmer and Ottenbreit-Leftwich, 2013).

[3] Corresponding author's address: Zonguldak Bulent Ecevit University, Ereğli Faculty of Education, Department of Mathematics Education, Ereğli, Zonguldak, Turkey
e-mail: yildiz.avni@gmail.com

[1] This manuscript is a part of the first author's master thesis, completed under the supervision of the second author.

Today, education and technology are two interdependent concepts (Komis, Ergazakia and Zogzaa, 2007; McCannon and Crews, 2000). Therefore, integrating technology into education is seen as an important part of effective teaching (Pierson, 2001). In order to integrate technology effectively into education, teachers need to have pedagogical knowledge and skills about how to apply these technologies, as well as knowledge of technology (Cox, Abbott, Webb, Blakely, Beauchamp and Rhodes, 2004). However, technology knowledge, knowledge of the content and knowledge of the content-specific pedagogical method require other approaches due to the fact that technology integration knowledge is limited to technology courses (Mishra and Koehler, 2006). The theoretical framework called Technological Pedagogical Content Knowledge (TPACK) has been introduced by Mishra and Koehler (2006) to answer those problems. TPACK has a dynamic structure and different methods are used to understand this structure (Jen, Yeh, Hsu, Wu, and Chen, 2016). The TPACK model expands the concepts of pedagogical content knowledge (PCK) by adding technology to a particular type of teacher knowledge (Mishra and Koehler, 2006). TPACK is an educational framework that includes many uses of technology in the classroom (Young, Young, Hamilton and Pratt, 2019). While TPACK is defined as teachers' knowledge of when, where and how to use technology, it guides students to increase their knowledge and skills in specific content areas by using appropriate pedagogical approaches (Brantley-Dias and Ertmer, 2013; Niess, 2011). The TPACK model emphasizes the importance of interactions of the three areas that teachers need to integrate technology into the teaching. These are technological knowledge (TK), pedagogical knowledge (PK) and content knowledge (CK) (Koehler, Mishra and Cain, 2013). Mudzimiri (2012) stated that it is not realistic to expect that the TPACK of teachers developed immediately, which is why he said that they could be affected by many factors (technology experience, knowledge of the content, technology beliefs). In order to determine the teachers' TPACK levels, it was argued that it would be more accurate to analyze the lesson plans and the activities they prepared and to reach the conclusion according to the data obtained (Akyüz, 2016).

It is not enough for teachers to have the subject area. Creative teachers with their confidence, motivation and abilities can develop and implement learning methods and strategies according to students (Lince, 2016). On the other hand, there is much emphasis on technology to support pedagogical developments and, in particular, on the types of pedagogy that support students to develop the twenty-first century competencies (ISTE, 2007). Considering the characteristics that should be in teaching, it is seen that the importance of the individuals not only thinking about them, but also evaluating and reflecting on their thoughts and practices.

Mathematics teaching with technology, is of great importance and emphasized according to the National Council of Mathematics Teachers in the United States, the Curriculum and Evaluation Standards for School Mathematics 1989, the Professional Standards for Teaching Mathematics 1991 and the Assessment Standards for School Mathematics 1995. In other words, mathematics should be given as a logical, analytical, systematic, critical and creative thinking ability and at the same time the ability to cooperate, thus mathematics can be considered as a network concept (Lince, 2016). Therefore, the potential of dynamic mathematics software can be used when teaching mathematics. The development of new technologies in the twenty-first century and the resulting focus on digital problem-solving skills require the use of technology in educational environments (Siddiq, Hatlevik, Olsen, Throndsen & Scherer, 2016; van Laar, Van Deursen, Van Vej & de Haan, 2017). This may allow TPACK components to interact with each other.

TPACK assist the teacher in the proper selection and integration of technology in the pedagogy to be used and in the content to be taught to the students (Arora and Pany, 2018). Arora and Pany (2018) stated that they can create a dynamic and interactive learning environment in the classroom with interactive software such as GeoGebra, Geometer Sketchpad, and that concrete and virtual manipulative-based activities can contribute to increasing the effectiveness of technology-oriented pedagogies. Through the features of dynamic geometry software abstract mathematical relations can be easily embodied (Karataş, Pişkin – Tunç, Demiray and Yılmaz, 2016). GeoGebra is one of the most widely used dynamic software and the combination of both algebra and geometry and common use of features (Hohenwarter and Jones, 2007). GeoGebra has a significant place in education. While teaching Analytical Geometry, it was found that using GeoGebra as a didactic approach, comparing with traditional methodology, improves the performance of mathematics; at the same time, it was found that motivation, personal awareness and students' participation in the learning process increased (Costa, 2011). However, it allows students to visualize problems as well as avoid algebraic obstacles (Bu and Schoen, 2012). In addition, GeoGebra studies generally aim to examine the views of students, teachers or prospective teachers about this software and the effects of the software on students, teachers, prospective teachers and learning environments (Baltacı & Baki, 2017; Baltacı, Yıldız and Kösa, 2015). But it is necessary to involve on mathematics teachers' TPACK in detail during their classroom activities design processes using GeoGebra.

When the studies related to the TPACK are examined, it was determined that most of the studies were about the teachers' or teacher candidates' TPACK competencies, measured in class environment and about the scale, developed for TPACK. However, with this study, it is aimed to develop a valid, reliable and useful form of observation to determine the TPACK usage status of mathematics teachers while preparing activities in an extracurricular environment with GeoGebra software. In this regard, information was given about the process of development of the observation form and the processes carried out in this process were put forward. Thus, an important contribution can be made to the relevant literature on the TPACK concept, which is becoming more and more important in the world. In this context, it can be said that the study might be an original one when the studies are examined.

## 2. Methodology

In this chapter; information about the research group, process and data analysis are going to be shown.

### 2.1. Research Group

It is not enough to write some guidelines in order to obtain a valid, useful and reliable form of observation for the secondary school mathematics teachers to examine their behavior in the TPACK context while developing activities with GeoGebra software. In the study, theoretical form was used in accordance with expert opinions for content validity studies. In the theoretical process, a qualitative study can be conducted by taking expert opinions about the items in the candidate scale form in case of failure of large sampling. In this context, the expert group of this research consists of 5 faculty members who are specialized in the field of TPACK and 15 mathematics teachers who study postgraduate studies in the field of TPACK. Thus, this qualitative process can be transformed into a statistical quantitative process with the help of content validity ratios (McGartland, Berg-Weger, Tebb, Lee and Rauch, 2003).

**Table 1.** Descriptive profile of the participants

| Subscale | | 1 | 2 | 3 | 4 | 5 | Total |
|---|---|---|---|---|---|---|---|
| **Gender** | | Male | Female | | | | |
| | *f* | 12 | 8 | | | | 20 |
| | % | 60 | 40 | | | | 100 |
| **Age** | | 25-30 | 31-35 | 36-40 | 41-45 | 46-50 | |
| | *f* | 5 | 5 | 8 | 1 | 1 | 20 |
| | % | 25 | 25 | 40 | 5 | 5 | 100 |
| **Seniority** | | 1-10 | 11-15 | 16-20 | 21-25 | +26 | |
| | *f* | 10 | 5 | 5 | | | 20 |
| | % | 50 | 25 | 25 | | | |

### 2.2. Process

The research was conducted in three phases, namely preparation, piloting and evaluation.

While the data were collected for the behaviors that could be added to the observation table, seven sub-dimensions in the conceptual framework for TPACK presented by Mishra and Koehler (2006) were guiding. In addition, TPACK scale development studies in the literature (Archambault and Crippen, 2009; Schmidt et al., 2009; Kabakci Yurdakul et al., 2012) have contributed to the formation of the observation form. Thus, the information in the literature is gathered and expressed as the behaviors that teachers can show.

When the behaviors were transferred to the observation form, a wide range of literature was investigated and consulted with colleagues by considering the purpose of the study. In addition, it was added to the observation form by discussing with the field experts how teachers can exhibit their TPACK competences in a non-teaching environment with dynamic software.

A draft observation form was prepared following the above processes. This observation form was used during pilot application. The pilot study was conducted with two teachers who were teachers of mathematics in primary schools.

In this process, 5 activities of each teacher were observed and a total of 10 activities were examined. As a result of the pilot study, there were some deficiencies in the observation form. For this reason, it was decided to make some changes based on the opinions received from the field experts. In addition, these behaviors were added to the observation form as they showed some behaviors not shown in the observation form during the pilot study process. These items are "The teacher organized the activities in consideration of how many lesson hours are required to achieve learning results of a subject.", "The teacher effectively adapted the subject content that they will need while teaching the topic into GeoGebra software." and "The teacher could turn the abstract meanings into concrete outcomes based on their past mathematical experiences". Then, the order of behaviors in each step in the observation form were changed by taking into account the sequence of behaviors as a result of long-term observations in the pilot study. After these changes, the observation form was revised by the researcher and finalized with the studies for the content validity.

2.3. Data Analysis

During the development of the observation form, expert opinions were consulted and theoretical form was used for each behavior item.

Lawshe technique was used to determine content validity ratios. Lawshe technique consists of 6 stages. The aim of this study is to establish the group of field experts, to prepare the candidate scale forms, to obtain expert opinions, to obtain content validity ratios for the items, to obtain the content validity index for the scale and to establish the original form according to the content validity rates / index criteria (McGartland et al. 2003).

*a. Establishment of the experts group*: The expert group of this research consists of 5 faculty members who are specialized in the field of TPACK and 15 mathematics teachers who study postgraduate studies in the field of TPACK.

*b. Preparation of candidate scale forms:* After the pilot study, some changes were made on the candidate observation form and the experts were asked to indicate the writability of the behaviors that the teachers could show. Each item of the form prepared for this were *"necessary", must be corrected", "unnecessary"* and the experts were asked the relevant ratings for each item. In addition, the experts were asked to write down their comments on the behaviors in the form and on the behaviors they wanted to add.

*c. Evaluation of expert opinions:* After evaluating the observation charts, the responses of the experts were evaluated in a single form. Thus, it has been shown how many experts have been approved, not given, or wanted to make changes to items in a single form.

*d. Obtaining content validity ratios for items:* The content validity ratios for each item were determined in the next stage. The rate of the content validity is expressed as subtraction of 1 from the ratio of the percentage of the number of expert's opinion indicating "necessary" statement regarding any item to the percentage of half of the total number of experts indicating their opinions based on the respective item.

*e. Obtaining content validity indexes for the scale:* Arithmetical averages of content validity ratios were obtained and content validity indexes were obtained.

*f. Establishing the final form according to the content validity / index criteria:* The steps to obtain the final version of the observation form were repeated from step b, as some experts expressed their views on the observation form.

## 3. Findings

If the content validity criteria (CVRs) values contain negative or 0 values, such substances are the ones that are eliminated in the first place. For the items with positive CVRs values, statistical criteria and their significance are tested. In order to test the statistical significance of the CVRs, the minimum values of the CVRs at a level of $\alpha$ = 0.05 significance were converted into a table by Veneziano and Hooper (1997). Thus, the minimum values for the number of experts also indicate the statistical significance of the substance. According to this, the minimum value of the content validity ratios for the 20 experts at $\alpha$ = 0.05 significance level was taken as 0.42. Therefore, these behaviors were excluded from the observation form because the content validity ratio of 5 items was less than 0.42.

After these 5 items were excluded from the observation form, the arithmetic averages of the content validity ratios of the items and the content validity indexes were obtained. It was concluded that the content validity of the observation form was statistically significant because the content validity indexes obtained for each section were greater than the minimum value (0.42) of the content validity ratios determined for 20 experts. The above statistical calculations for the observation form obtained in this context are shown in Table 2.

**Table 2.** Evaluation of expert opinion and observation form

| | Suitability of Behaviors for Purpose | | | |
|---|---|---|---|---|
| | Necessary | Correction needed | Unnecessary | Content Validity Ratio |
| 1. The teacher revised the subject requirements (environment, time, etc.) appropriately. | 20 | | | 1,00 |
| 2. The teacher made use of the technological tools backed by communication (Google, GeoGebraTube, forum, etc.) in designing course activities. | 19 | 1 | | 0,90 |
| 3. The teacher could generally keep their technological capabilities up-to-date. | 17 | | 3 | 0,70 |
| 4. The teacher dealt with the problems faced during the designing process in an interdisciplinary way while using technology. | 17 | | 3 | 0,70 |
| 5. The teacher organized their activity design in line with the requirements of GeoGebra. | 18 | 2 | | 0,80 |
| 6. The teacher could manage the efficiency of the design process in an optimized way. | 13 | 1 | 6 | 0,30 |
| 7. The teacher was able to predict the possible issues that can be experienced in every part of the designing activity process and made necessary provisions. | 16 | 3 | 1 | 0,60 |
| 8. The teacher held to the teaching profession ethics in every part of the designing activity process. | 16 | 3 | 1 | 0,60 |
| 9. The teacher determined the teaching perspective in accordance with the subject while designing activities. | 18 | 2 | | 0,80 |
| 10. The teacher organized and clarified the set of concepts (from simple to complex and general to specific) in the designing activity process. | 19 | 1 | | 0,90 |
| 11. The teacher planned the course activities in line with the lesson plan of mathematics syllabus. | 20 | | | 1,00 |
| 12. The teacher anticipated the estimated students' misunderstanding and organized the subject activities considering such misconceptions. | 18 | 2 | | 0,80 |
| 13. The teacher acquired field knowledge that was not necessary and was specific to teaching in educational environments. | 7 | 2 | 11 | -0,30 |
| 14. The teacher clarified the course concepts and the information about the process according to the needs of technology use. | 18 | 2 | | 0,80 |

| | | | | |
|---|---|---|---|---|
| 15. The teacher was knowledgeable about the latest updates regarding their field. | 17 | 3 | | 0,70 |
| 16. The teacher linked and blended the elements of pedagogy, content, and knowledge of technology. | 20 | | | 1,00 |
| 17. The teacher could explain the subject in a way that concretizes the interpretation referring to their past experiences in the field of mathematics. | 18 | | | 0,80 |
| 18. The teacher was knowledgeable about the current curriculum. | 17 | | 3 | 0,70 |
| 19. The teacher utilized and shaped their thinking styles in accordance with mathematics. | 11 | 4 | 5 | 0,10 |
| 20. The teacher adapted and revised the content of the course activities in the designing process in some parts where students could face possible learning problems. | 16 | 4 | | 0,60 |
| 21. The teacher designed the teaching content in a way that introduces scenarios based upon problem-solving skills. | 20 | | | 1,00 |
| 22. The teacher could manage to reflect their problem-solving skills on the activity designing process. | 12 | 2 | 6 | 0,20 |
| 23. The teacher attempted to associate the course content with real-life issues in designing the activities. | 18 | 1 | 1 | 0,80 |
| 24. The teacher could synchronically revise and re-design a course activity when necessary throughout the designing process. | 18 | 1 | 1 | 0,80 |
| 25. The teacher set objectives which were directly aimed at learning outcomes while planning the course activity. | 19 | 1 | | 0,90 |
| 26. The teacher applied their terms and symbols specific to the field of mathematics correctly. | 17 | | 3 | 0,70 |
| 27. The new information was transferred by retrieval of old information during the activity designing process. | 15 | 3 | 2 | 0,50 |
| 28. The teacher employed sufficient GeoGebra skills with the purpose of teaching the subject during the activity designing process. | 11 | 4 | 5 | 0,10 |
| 29. GeoGebra software was properly integrated with teaching techniques during the activity designing process. | 20 | | | 1,00 |

***Content Validity Ratio: 0.42, *Content Validity Index after 5 items are released: 0.79**

Since some experts have expressed the opinion that some of the behaviors are included in the observation form, steps have been repeated starting from step b of Lawshe technique to obtain the final version of the observation form. In Table 1, three behaviors were added to the statistically significant behaviors. Thus, the experts were provided to view the scale as a whole and were asked to re-evaluate all behaviors. The result of the observation table is given in Table 3.

**Table 3.** Finalization of observation form

| Behaviors | Descriptions |
|---|---|
| 1. The teacher revised the subject requirements (environment, time, etc.) appropriately. | |
| 2. The teacher made use of the technological tools backed by communication (Google, GeoGebraTube, forum, etc.) in designing course activities. | |
| 3. The teacher generally kept their technological capabilities up-to-date. | |
| 4. The teacher dealt with the problems faced during the designing process in an interdisciplinary way while using technology (GeoGebra). | |
| 5. The teacher organized their activity design in line with the requirements of GeoGebra. | |
| 6. The teacher was able to predict the possible issues that can be experienced in every part of the designing activity process and made necessary provisions. | |
| 7. The teacher held to the teaching profession ethics in every part of the designing activity process. | |
| 8. The teacher determined the teaching perspective in accordance with the subject while designing activities. | |
| 9. The teacher organized and clarified the set of concepts (from simple to complex and general to specific) in the designing activity process. | |
| 10. The teacher planned the course activities in line with the lesson plan of mathematics syllabus. | |
| 11. The teacher anticipated the estimated students' misunderstanding and organized the subject activities considering such misconceptions. | |
| 12. The teacher organized the activities in consideration of how many lesson hours are required to achieve learning results of a subject. | |
| 13. The teacher effectively adapted the subject content that they will need while teaching the topic into GeoGebra software. | |
| 14. The teacher effectively assigned the operations knowledge into GeoGebra software. | |
| 15. The teacher was knowledgeable about the latest updates regarding their field. | |
| 16. The teacher linked and blended the elements of pedagogy, content, and knowledge of technology. | |

17. The teacher could turn the abstract meanings into concrete outcomes based on their past mathematical experiences.

18. The teacher could explain the subject in a way that concretizes the interpretation referring to their past experiences in the field of mathematics.

19. The teacher planned the course activities in such a creative way that students could develop mathematical thinking skills.

20. The teacher adapted and revised the content of the course activities in the designing process in some parts where students could face possible learning problems.

21. The teacher designed the teaching content in a way that introduces scenarios based upon problem-solving skills.

22. The teacher attempted to associate the course content with real-life issues in designing the activities.

23. The teacher could synchronically revise and re-design a course activity when necessary throughout the designing process.

24. The teacher set objectives which were directly aimed at learning outcomes while planning the course activity.

25. The teacher applied their terms and symbols specific to the field of mathematics correctly.

26. The new information was transferred by retrieval of old information during the activity designing process.

27. GeoGebra software was properly integrated with teaching techniques during the activity designing process.

## 4. Discussion, Conclusion and Suggestions

Abbitt (2011) stated that teachers should use technology effectively and meaningfully to support students' learning process. In this context, Technological Pedagogical Content Knowledge (TPACK) has an important place in terms of the fact that teachers / teacher candidates use technology in the learning-teaching process (Graham, 2011).

A teacher with TPACK should be able to integrate technology with content knowledge and create opportunities for students to explore mathematical knowledge. TPACK is the information necessary to effectively adapt and regulate existing technology with developmentally and contextually appropriate methods and contents (Sickel, 2019). Since TPACK is a recent concept (Mudzimiri, 2012), it is necessary for teachers to understand, conceptualize/internalize and effectively apply the concept for each innovation (Baki, 2002). In this context, it can be said that teachers and educators should learn how to develop their TPACK in order to increase the practices by guiding the planning of pedagogical improvements in lesson planning and practice.

Although technology integration is seen as an integral part of good teaching (Pierson, 1999), teachers are required to develop their skills in using the technological knowledge and technology in the teaching process (Niess, 2005; Niess, 2011). Sickel (2019) said that for development, educators should focus on the theory of learning technology and pedagogy. The investigation of the curriculum shows that, science and technology are related. In order to embody the abstract concepts and to facilitate teaching of the lessons, materials that students can touch, hear and see should be more preferred. Therefore, Technological Pedagogical Content Knowledge (TPACK) is important for creating effective teaching materials for teachers. In the absence of Technological Pedagogical Content Knowledge, teachers may not be able to prepare more useful materials, and learning of students may not be more permanent. In order to integrate technology into education and training, a TPACK qualification is required by the teacher (Malik, Rohendi and Widiaty, 2018). With the observation form developed within the scope of this research, it might be determined how teachers exhibit their TPACK skills while preparing the activity with dynamic software and measures can be taken.

There is still a lack of knowledge on how TPACK structure is implemented by teachers when formulating technology-integrated courses to encourage learning in the twenty-first century (Cox and Graham, 2009; Graham, 2011). It is stated that the TPACK scale will be revealed not only by the teachers' TPACK scales but also by the tools such as interviews, prepared activities and lesson plans and it is stated that it will be more accurate to reach the conclusion (Akyüz, 2016). However, when the literature is examined, it is defined that mathematics teachers are not able to determine how to use TPACK in preparing activities with dynamic software. However, most of the items in this observation form are emphasized in the relevant literature as the learning environments in which TPACK and dynamic software are considered together. For example, *"The teacher created the activity by combining content, pedagogy and technology knowledge"* is important item, because Koehler and Mishra (2008) have emphasized that teachers need to know the knowledge structures related to pedagogy, content and technology knowledge in order to integrate technology effectively into their courses. In addition, the item of *"The teacher correctly used its own unique symbols and terms of mathematics"* is also important for accurately reflecting the thought on mathematical relations as mentioned in NCTM (1989). Another item, *"The teacher was able to predict the possible issues that can be experienced in every part of the designing activity process and made necessary provisions"* is also in this observation form because teaching mathematics should be seen not only as a transfer of mathematical knowledge, but also as an improvement of the student's abilities and skills, which are even more important (Ozgen & Kutluca, 2013).

For this reason, it is thought that the observation form which has been going through the above processes will help individuals to do research in this direction. The observation form obtained in this direction can be used for different subjects in different contexts.

**5. 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.

Açıkgöz, K. Ü. (2005). *Etkili öğrenme ve öğretme [Effective learning and teaching].* İzmir: Educational World Publications.

Akyüz, D. (2016). Farklı öğretim yöntemleri ve sınıf seviyesine göre öğretmen adaylarının TPAB analizi [TPACK analysis of preservice teachers under different instruction methods and class levels]. *Turkish Journal of Computer and Mathematics Education, 7*(1), 89-111.

Archambault, L., & Crippen, K. (2009). Examining TPACK among K-12 online distance educators in the United States. *Contemporary Issues in Technology and Teacher Education, 9*(1), 71-88.

Arora, S., & Pany, S. (2018). Redesigning the mathematics classroom through TPACK enriched pedagogical strategies. *Pedagogy of Learning, 4*(3), 1-9.

Baki, A. (2002). *Bilgisayar destekli matematik [Computer aided mathematics].* Istanbul: Ceren Publications.

Baltacı, S. & Baki, A. (2017). Bağlamsal öğrenme ortamı oluşturmada GeoGebra yazılımının rolü: Elips Örneği [The role of GeoGebra software in constructing a contextual learning environment: The case of ellipse]. *Ahi Evran University Journal of Kırşehir Education Faculty (JKEF), 18*(1), 429-449.

Baltacı, S, Yıldız, A. & Kösa, T. (2015). Analitik geometri öğretiminde GeoGebra yazılımının potansiyeli: Öğretmen adaylarının görüşleri [The potential of GeoGebra dynamic mathematics software in teaching analytic geometry: The opinion of pre-service mathematics teachers]. *Turkish Journal of Computer and Mathematics Education, 6*(3), 483-505.

Brantley-Dias, L., & Ertmer, P. A. (2013). Goldilocks and TPACK: Is the construct "just right? *Journal of Research on Technology in Education, 46*(2), 103- 127.

Bu, L., & Schoen, R. (2012). *Model-centered learning: Pathways to mathematical understanding using GeoGebra.* Rotterdam: Sense Publishers.

Costa, J. (2011). Plataforma de matematización en un entorno GeoGebra dentro de un planteamiento didáctico «desde abajo hacia arriba [Mathematization platform in a GeoGebra environment within a didactic approach «from bottom to top]. *Enseñanza las Ciencias, 29*(1), 101– 114.

Cox, S., & Graham, C. R. (2009). Diagramming TPACK in practice: Using an elaborated model of the TPACK framework to analyze and depict teacher knowledge. *TechTrends, 53*(5), 60-69. doi:10.1007/s11528-009-0327-1.

Cox, M., Abbott, C., Webb, M., Blakely, B., Beauchamp, T., & Rhodes, V. (2004). ICT and Pedagogy – A review of the literature. *ICT in Schools Researc hand Evaluation Series*, *18*.

Ertmer, P., & Ottenbreit-Leftwich, A.T. (2013). Removing obstacles to the pedagogical changes required by Jonassen's vision of authentic technology-enabled learning. *Computers & Education, 64*, 175-182.

Graham, C.R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education, 57*, 1953-1960.

Hohenwarter, M., & Jones, K. (2007). Ways of linking geometry and algebra: The case of GeoGebra. *Proceedings of the British Society for Research into Learning Mathematics*, *27*(3), 126-131.

International Society for Technology in Education (ISTE) (2007). *National educational technology standards and performance indicators for students.* Eugene.

Jen, T. H., Yeh, Y. F., Hsu, Y. S., Wu, H. K. & Chen, K. M. (2016). Science teachers' TPACK-practical: Standard-setting using an evidence-based approach. *Computers and Education, 95,* 45–62.

Joo, Y. J., Park, S., & Lim, E. (2018). Factors influencing preservice teachers' intention to use technology: TPACK, teacher self-efficacy, and technology acceptance model. *Educational Technology & Society*, *21*(3), 48–59.

Kabakci-Yurdakul, I., Odabaşı, H. F., Kılıçer, K., Çoklar, A. N., Birinci, G., & Kurt, A. A. (2012). The development, validity and reliability of TPACK-deep: A technological pedagogical content knowledge scale. *Computers and Education, 58*(3), 964-977.

Karataş, İ., Pişkin-Tunç, M., Demiray, E., Yılmaz, N. (2016). Öğretmen adaylarının matematik öğretiminde teknolojik pedagojik alan bilgilerinin geliştirilmesi [The development of pre-servıce teachers' technological pedagogical content knowledge in mathematics instruction]. *Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi, 16*(2), 512-533.

Koehler, M. J., & Mishra, P. (2008). Introducing TPCK AACTE committee on innovation and technology (Ed.). *The handbook of technological pedagogical content knowledge (TPCK) for educators.* Mahwah, NJ: Lawrence Erlbaum Associates, 3- 29.

Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content knowledge? *Journal of Education, 193*(3), 13-19.

Komis, V., Ergazakia, M., & Zogzaa, V. (2007). Comparing computer-supported dynamic modeling and "paper and pencil" concept mapping technique in students' collaborative activity. *Computers and Education, 49*(4), 991-1017.

van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literatüre review. *Computers in Human Behavior*, *72*, https://doi.org/10.1016/j.chb.2017.03.010.

Lince, R. (2016). Creative thinking ability to increase student mathematical of junior high school by applying models numbered heads together. *Journal of Education and Practice*, Vol.7, No.6.

Malik, S., Rohendi, D. & Widiaty, I. (2018). Technological pedagogical content knowledge (TPACK) with information and communication technology (ICT) integration: A literature review. *In 5th UPI International Conference on Technical and Vocational Education and Training (ICTVET 2018).* Atlantis Press.

McCannon, M., & Crews, T. B. (2000). Assessing the technology needs of elementary school teachers. *Journal of Technology and Teacher Education, 8*(2), 111-121.

McGartland, R. D., Berg Weger, M., Tebb, S., Lee, E. S., & Rauch, S. (2003).Objectifying content validity: Conducting a content validity study in social work research. *Social Work Research,* 27(2), 94-104.

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

Mudzimiri, R. (2012). *A study of the development of technological pedagogical content knowledge (TPACK) in pre-service secondary mathematics teachers*. Doctoral Dissertation, Retrieved from ProQuest Dissertations and Theses. (Publication No. 3523442).

National Council of Teachers of Mathematics. (1989). *Principles and standards for school mathematics*. Reston, VA: Author.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

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

Niess, M. L. (2011). Investigating TPACK: Knowledge growth in teaching with technology. *Journal of Educational Computing Research, 44*(3), 299-317. doi:10.2190/EC.44.3.c.

Ozgen, K. & Kutluca, T. (2013). İlköğretim matematik öğretmen adaylarının matematik okuryazarlığına yönelik görüşlerinin incelenmesi [An İnvestigation of primary mathematics pre-service teachers' views towards mathematical literacy]. *Dicle Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*. 5 (10), 1308-6219.

Pierson, M. E. (1999). *Technology practice as a function of pedagogical expertise*. (Postgraduate thesis), Arizona State University, Arizona.

Pierson, M. E. (2001). Technology practice as a function of pedagogical expertise. *Journal of Research on Computing in Education, 33*(4), 413- 430.

Schmidt, D., Baran, E., Thompson, A., Mishra, P., Koehler, M. J., & Shin, T. (2009). *Technological pedagogical content knowledge (TPACK): The development and validation of an assessment instrument for preservice teachers*. Paper presented at the 2009 Annual Meeting of the American Educational Research Association. April 13-17, San Diego, California.

Sickel, J (2019). The great media debate and TPACK: A multidisciplinary examination of the role of technology in teaching and learning. *Journal of Research on Technology in Education*, *51* (2), 152-165.

Siddiq, F., Hatlevik, O. E., Olsen, R. V., Throndsen, I., & Scherer, R. (2016). Taking a future perspective by learning from the paste a systematic review of assessment instruments that aim to measure primary and secondary school students' ICT literacy. *Educational Research Review, 19*, https://doi.org/10.1016/j.edurev.2016.05.002.

Veneziano, L., & Hooper, J. (1997). A method for quantifying content validity of health related questionnaires. *American Journal of Health Behavior*, *21*, 67-70.

Young, J.R., Young, J., Hamilton, C., & Pratt, S. (2019). Evaluating the effects of professional development on urban mathematics teachers TPACK using confidence intervals. *REDIMAT – Journal of Research in Mathematics Education*, *8*(3), 312-338. doi: 10.4471/redimat.2019.3065.