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The Effect Of Digital Storytelling On The Development Of Preservice Mathematics Teachers' Technological Pedagogical Content Knowledge

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ABSTRACT
Digital storytelling (DST) is, in general terms, a form of storytelling created by incorporating technological elements into traditional storytelling. DST has begun to be used frequently in education. Digital stories are utilised to provide information or instruction on personal stories, historical events or a specific subject. One of the subjects studied is the effect of DST on the Technological Pedagogical Content Knowledge (TPACK) of teachers and prospective teachers. DST helps to integrate the curriculum, pedagogy and technology holistically with advantages such as active participation, development of skills and development of the learner as a person. The aim of this study is to examine the effect of DST on the development of TPACK in preservice secondary mathematics teachers. A transformative mixed research method was used in the study. The participants were 44 preservice mathematics teachers studying in their final year at a state university in Turkey. The data were obtained through a demographic form, the TPACK-Math scale, lesson plans and interviews. For the data analysis, the paired samples t-test, Wilcoxon signed-rank test, Shapiro-Wilk test and TPACK diagram were used. As a result of the research, it was seen that DST enabled the development of the preservice teachers' TPACK knowledge. In addition, it was determined that the prospective teachers felt most comfortable in using the software, whereas they had the most difficulty in creating the script.

Keywords: Digital storytelling, mathematics education, technological pedagogical content knowledge, preservice secondary mathematics teacher

INTRODUCTION

Technological Pedagogical Content Knowledge (TPACK) is aimed at teachers and preservice teachers, and defines the types of knowledge needed to successfully integrate technology into teaching (Mishra, 2019). Moreover, it is also used to define and understand the intended targets for the use of technology in teacher education (Schmidt et al., 2009). This "overarching construct....has been proposed as the interconnection and intersection of technology, pedagogy and content knowledge" (Niess et al., 2009). Both theoretically and practically, the interaction of these bodies of knowledge generates the flexible types of knowledge needed to successfully integrate the use of technology into teaching (Koehler et al., 2013). Furthermore, TPACK is especially useful in conceptualising how to utilise the opportunities provided by technology to improve teaching and learning (Archambault & Barnett, 2010) and in enabling teachers to teach students effectively and use technology effectively in this teaching (McGraw-Hill Education, 2020). Technology use can only be effective when teachers have the expertise to use it in the classroom in a meaningful way (Sadık, 2008). In this sense, preparing preservice teachers for technology integration in the classroom is a key focus for many teacher training institutions (Chai et al., 2010).

In developing TPACK, which is a teacher education framework, different pedagogical approaches are utilised. One of these is Digital Storytelling (DST) (Dewi, 2016; Harriman, 2011). DST is expressed as the use of various computer-based tools to tell a story (Robin, 2015). Creating a digital story requires the use of artistic, storytelling and project skills and abilities (Ohler, 2006). Barrett (2006) stated that DST is a tool for deep learning, while Van Gils (2005) stated that DST contributes to personalisation, real-life situations and active learning. DST is used to motivate both teachers and students (Robin, 2008). Reserchers state that by combining DST with the theoretical framework of TPACK in education, a deeper understanding will be achieved of the different and more powerful roles that digital media can play in both teaching and learning, because in order to fully understand the potential of DST, it is necessary to understand the technological knowledge, and this is also related to the TPACK framework (Hicks et al., 2013).

When the competencies are examined, it is seen that teachers' field, pedagogical and technological knowledge are emphasised. According to the findings of the TALIS (Teaching and Learning International Survey) study, which was conducted for the third time by the OECD in 2018, more than 85% of teachers in Turkey felt "quite" and "completely" prepared to teach in areas such as the content of the subjects, teaching methods, classroom practices, and following development and learning. The rate of those who felt "quite" and "completely" prepared for science and communication technologies was around 70% in Turkey. In addition, 66.6% of teachers in Turkey allowed students to use information and communication technologies (ICT) in their classroom practices. It is seen that this rate was 20.7% in the "PISA: Best in Asia" group and 44.3% in the "PISA: Best in Europe" group (TALIS, 2018).
The mathematical competences and basic competences in science/technology that teachers in the Ministry of National Education (MoNE, 2018) should have are explained as follows:
"Mathematical competence is the development and application of mathematical thinking to solve a range of problems encountered in daily life. Emphasis is placed on the process, activity and knowledge built on a solid arithmetic skill. Mathematical competence includes the ability and desire to use mathematical modes of thinking (logical and spatial thinking) and presentation (formulas, models, constructs, graphs and tables) in varying degrees. Competence in science refers to the wealth of knowledge and the ability and desire to utilise methodology to explain the natural world in order to define questions and generate evidence-based conclusions. Competence in technology is regarded as the implementation of knowledge and methodology in the context of fulfilling perceived human desires and needs. Competence in science and technology encompasses the power to understand changes resulting from human activities and the responsibilities of each individual as a citizen."
Furthermore, digital competence is explained thus:
"This comprises the safe and critical use of information and communication technologies for business, daily life and communication. This competence is supported through basic skills such as using computers to access, evaluate, store, generate, present and exchange information, as well as enabling participation in common networks and establishing communication via the internet" (MoNE, 2018).
When the general competencies and particularly the competencies for mathematics education in Turkey are examined, it is seen that technology is given importance in teacher training. Rather than technological knowledge alone, it is necessary to integrate this into the field with appropriate methods and techniques. This is evaluated within the scope of TPACK. In fostering the competencies of the teaching profession, it is necessary to include the training process of preservice teachers alongside in-service training. For this reason, in this study, we aim to improve preservice secondary mathematics teachers' TPACK knowledge by blending their curriculum, content and technological knowledge through DST.

Tpack

Along with educators' realisation that technological skills alone do not serve them well, the question of how to integrate technology into teaching has become the focus of studies (Graham et al., 2009). For this reason, the TPACK conceptual framework for educational technology was created based on Shulman's Pedagogical Content Knowledge (PCK) framework (Mishra & Koehler, 2006; Niess, 2005). Based on the changes in technology, students, teachers and classroom contexts, TPACK provides a dynamic framework for teachers to display the necessary knowledge for curriculum design, and for students, instruction that prepares them to think about and learn the subject with digital technologies (Niess et al., 2009). A strong TPACK framework can provide theoretical guidance for teacher training programmes to raise teacher candidates who are required to use technology (Graham, 2011). Mishra and Koehler (2006) identified seven components related to the TPACK structure:

1. Content Knowledge (CK): This concerns the subject related to the field that needs to be learnt or taught.
2. Pedagogical Knowledge (PK): This is knowledge of teaching approaches and methods.
3. Technological Knowledge (TK): This is knowledge about standard and digital technologies.
4. Pedagogical Content Knowledge (PCK): This is knowledge of the teaching methods that can be used in subject teaching.
5. Technological Pedagogical Knowledge (TPK): This is knowledge of technological competencies and how these can change teaching.
6. Technological Content Knowledge (TCK): This is the knowledge that technological and content knowledge are related.
7. TPACK: This is knowledge about technologies and teaching approaches that can be used to teach a specific subject related to the field.

Teaching with technology is a difficult task to perform well, because teaching successfully with technology requires continuity. For this reason, it is necessary to create, maintain and re-establish a dynamic balance between all components (Koehler & Mishra, 2009). TPACK strategic thinking involves knowing when, where and how to use domain-specific knowledge and strategies to direct students' learning with appropriate information and communication technologies (Niess, 2011).

Dst and Mathematics Education

The concept of DST was developed by Dana Atchley, Joe Lambert and Nina Mullen in the early 1990s (StoryCenter, 2022). In general terms, the digital story is the art of storytelling with add-ons such as sound, images, music and video. Digital stories are several minutes long. Digital stories are utilised to provide information or instruction on personal stories, historical events or a specific subject (Robin, 2006). DST is a powerful form of communication achieved through the use of software applications to explore different media and to relate stories in new and powerful ways using digital media (McLellan, 2007).

Jakes and Brennan (2005) defined six steps in creating a digital story. First, the story is written, the script is developed, and the storyboard is created. Then, by utilising technology, multimedia tools are selected and a digital story is created. In the last step, the created digital story is shared. Lambert and Hessler (2018), however, stated that there are seven elements in digital storytelling. These are self-disclosure, soundtrack, experience, artwork, music, length and design, and purpose.

Due to its ability to serve as a powerful tool for both educators and students, one of the most common uses of DST is in education. Among the benefits of DST for students are the acquisition of 21st century literacy skills, which are stated as a critical need for learning, working and advancing in today's technology-intensive world (Robin & McNeil, 2019). According to Robin (2016), students who participate in the creation of digital stories develop communication skills by learning how to organise their ideas, ask questions, express their views and create narratives. Students who have the opportunity to share their work with their peers can gain valuable experience in criticising their own and other students' work, which can promote gains in emotional intelligence, collaboration, and social learning. Ohler (2006), moreover, stated that DST helps students to become active participants rather than passive consumers in a media-saturated society. Preparing digital stories is a useful method to motivate preservice teachers and promote learning (Yang & Wu, 2012). Alabbasi (2018) stated that creating digital stories provides teachers with a positive perception of technology integration.

Mathematics is defined as a difficult and complex subject which includes abstract concepts. For this reason, it is considered appropriate to use DST in this subject, as DST makes it easier to explain abstract and difficult concepts and involves students in the process (Albano & Pierri, 2014). DST develops the content knowledge and pedagogical competence of prospective mathematics teachers (Istenic Starčič et al., 2016). Moreover, it supports student participation in order to ensure better learning (Albano & Pierri, 2017). DST is a powerful tool for creating more interesting and entertaining learning environments that make it easier to associate mathematics with daily life and enable effective learning and participation (Özpınar, Gökçe & Yenmez, 2017). DST is also effective in problem solving and creation (Walters et al., 2018), and algorithmic and logical thinking (Kordaki & Kakavas, 2017). It also improves mathematical and computer literacy skills (Preradovic, Lesin & Boras, 2016) and the level of conceptual understanding (Dinçer, 2019). While DST encourages students to generate hypotheses (Albano et al., 2020), it increases motivation and positive attitudes towards the subject of mathematics (Çakıcı, 2018). DST is also an important tool in eliminating errors and misconceptions (Karaoğlan Yılmaz et al., 2017) and in acquiring 21st century competencies (Niemi et al., 2018). In the literature, it is seen that in the studies on DST carried out with preservice teachers, product or opinion analyses are made (Büyükkarcı & Müldür, 2022; İnan, 2015; İslim, Özüdoğru & Sevim-Çirak, 2018; Özpınar, 2017).

TPACK and DST

The person who is to design a digital story should use CK and PK as well as technology-related factors (İncikabı & Kildan, 2013). Di Blas (2016) stated that teachers do not need to be trained on TK per se, but that instead, they should be trained on how to manage activities involving TK, since it is important for teachers to be able to organise students' work, even when faced with unfamiliar environments and situations. According to Hicks (2006), by creating and incorporating visual and audio data with digital stories, it is possible to use technology critically and at the same time develop TK and PCK. DST helps to integrate the curriculum, pedagogy and technology holistically with advantages such as active participation, development of skills and development of the learner as a person (Nerurkar, 2020). In addition, using TPACK and DST together is also effective in teaching 21st century skills (Lisenbee & Ford, 2018). TK serves as a guide for pedagogy in creating digital stories and events. Therefore, teachers should prepare digital stories by considering the components of TPACK and integrate them into the learning process with a holistic approach (Aksüt & Aydın, 2021). In the event that students become creative with digital storytelling, integration of the TPACK education model makes significant contributions to technology integration in teacher education (Yurdakul et al., 2013). In the development of skills in hybrid learning contexts, the ICT-TPACK design procedures have high educational potential with the aid of visual stories (De Rossi & Restiglian, 2019). With the help of the TPACK framework, the use of technology in DST improves teachers' ability to create meaningful learning experiences, and activates students' cognitive skills in both reading and writing as well as technical skills such as product skills (Amelia et al., 2021).

There are studies in the literature that associate the TPACK components with DST. For example, Yüksel-Aslan (2013) stated that TPACK is related to the digital story creation process in the following ways: Choosing the topic from the curriculum is related to CK, choosing and designing the message is concerned with PK, using various software to create the digital story concerns TK, creating the script is related to PCK, creating the storyboard is concerned with TCK, choosing the material is related with TPK, and the creation of the digital story is associated with TPACK. Clarke (2017), on the other hand, stated that CK is concerned with the personal story and experience, while story creation requires PK. In addition, adding the images and sound requires TK, the story content requires PCK, while seeing the content together with technological elements such as images and sound requires TCK. She stated that TPK, however, develops the pedagogical art of storytelling. Successful blending of all these elements develops TPACK. From a similar point of view, Aksüt and Aydın (2021) explained that TK determines the technologies (software programs) used by the participants while creating digital stories, while PK specifies the process of the integration of activity plans with digital stories. CK refers to the concepts that the participants wish to teach in their activity plans, while TPK expresses the inclusion of digital stories and pedagogical approaches in activity plans. It is stated that PCK refers to the use of the digital story-integrated activity plan in content education, and that TCK expresses how digital stories are used as an effective tool in the teaching of concepts. TPACK, on the other hand, is the combination of the entire process.

When the literature is examined, it is seen that there is a direct relationship between DST and TPACK and that DST develops TPACK. In mathematics education, however, studies on this subject are rather limited. For this reason, the aim of this study is to examine the effect of DST on the TPACK development of preservice secondary mathematics teachers. The research problem is: "What is the effect of DST on the TPACK development of preservice secondary mathematics teachers?" The sub-problems of the research are:

a) What is the change in preservice secondary mathematics teachers before and after DST implementation according to the TPACK-Math Scale?
b) What is the change in the lesson plans of preservice secondary mathematics teachers within the framework of TPACK before and after DST implementation?
c) At which stage do preservice secondary mathematics teachers feel most comfortable in the DST process according to the TPACK framework?
e) At which stage do preservice secondary mathematics teachers have difficulty in the DST process according to the TPACK framework?

METHOD

Research Design

In this study, a transformative mixed research method was used. In the transformative mixed research method, any data type (such as qualitative) is collected and analysed. Then, the obtained data are converted to another data type (such as quantitative) and analysed using another data analysis method. Based on the data obtained here, the findings are dealt with separately, and in the conclusion section, they are combined and general results are obtained (Tashakkori, Teddlie & Johnson, 2015). In order to observe the effect of DST on the changes in TPACK and its subcomponents among preservice secondary mathematics teachers, firstly, the TPACK-Math (Önal, 2016) scale was applied as a pre-test and post-test. In addition, the preservice teachers were asked to prepare lesson plans before and after DST according to the outcomes they chose, and the data were converted into quantitative data by scoring with an assessment rubric (Harris, Grandgenett & Hofer, 2010). With the aim of supporting the quantitative data, structured interviews were conducted with the teacher candidates. Both the qualitative and quantitative data are discussed and analysed separately in the findings section and combined and interpreted in the conclusion section.

Participants

A total of 44 preservice secondary mathematics teachers, 33 female and 11 male, who were studying in their final year at a state university in Turkey, participated in this study. Criterion sampling was used for the selection of the participants. Accordingly, it was determined as a criterion that the participants had taken undergraduate courses in curriculum and pedagogy, and especially in the technology-assisted mathematics teaching course. None of the participants had heard of the digital story concept or prepared a digital story before.

Data collection tools

Koehler, Shin and Mishra (2012) stated that five different measurements are commonly used to measure TPACK. These were expressed as self-report measures, open-ended questionnaires, performance assessments, interviews and observations. Developing an effective, reliable and valid tool is a difficult task (Lyublinskaya & Kaplon-Schilis, 2022). Although self-report questionnaires are mostly used to measure TPACK, the examination of lesson plans, which provide more objective measurements, has recently come into focus (Schmid, Brianza & Petko, 2021).

In this study, four types of data collection tools were used. The first was the Technological Pedagogical Content Knowledge Scale (TPACK-Math) developed by Önal (2016). This scale is a five-point Likert-type scale and is domain-specific. The scale includes TK (7 questions), PK (11 questions), CK (9 questions), TPK (3 online, 3 offline questions), TCK (5 questions), PCK (7 questions), TPCK (9 questions) and Contextual Knowledge (5 questions). According to the CFA results of the scale, the ratio of the chi-square value (2866.53) to the degree of freedom (1616) was 1.77. In addition, the goodness-of-fit values for the model revealed by CFA were SRMR=0.047 and RMSEA=0.050 (Önal, 2016). Another data collection tool was the lesson plans prepared by the teacher candidates in accordance with the outcomes they chose. The lesson plans were collected twice, before and after DST. Each preservice teacher was asked to choose a single outcome and to prepare for this outcome in both plans. The third data collection tool was the structured interviews. The interviews included two questions, which are:

1. At which stage did you feel most comfortable while preparing your digital story?
2. What were the elements that you had difficulty with while preparing your digital story?

For both questions, there are seven options: choosing the topic, choosing the message, creating the script, choosing the material, creating the storyboard, using the software, and combining the elements. The interview questions were prepared in the presence of two experts. The final data collection tool was the demographic form.

Implementation Process

The implementation process is presented in Table 1 in the form of weeks, subjects and practices:

Table 1 : Implementation Process

Weeks	Subjects	Practices
1	Making preliminary determinations	- The TPACK-Math scale was applied as a pre-test. - Each preservice teacher was asked to prepare a lesson plan by choosing any of the 5th and 6th grade outcomes.
2	General Information and DST	- The prepared lesson plans were collected electronically. - Information was given about the face-to-face and online practices to be carried out within the scope of the course. - The definition of DST and its types was given.
3-4	DST	- The seven elements that should be included in a digital story were described.
5	CK	- The importance of the narrator's determination of what he/she will relate in the digital story and who he/she will choose as the audience was explained. In other words, the importance of topic selection was mentioned.
6	PK	- The relevance of the message that the teacher will give to the student in the digital story design and the importance of the method by which this message will be given were mentioned.
7	PCK	- The importance of narrating the script according to the student's level in the chosen outcome was mentioned.
8	TPK	- The choice of audio-visual material for the script while creating the digital story was explained.
9	TCK	- The stage at which it is more appropriate to use DST in the lesson plan was discussed. - The storyboard was mentioned. The students were asked to prepare a storyboard about their stories.
10-11-12	TK	- Some of the software programs that can be used to design digital stories were explained online and face-to-face. - The advantages and disadvantages of these software programs were discussed by giving information.
13-14	TPACK	- The students were asked to design a digital story in accordance with the selected outcomes.
15	Making final determinations, collecting	- The TPACK-Math scale was applied as a post-test. - The final-determination lesson plans were collected.

	digital stories and conducting interviews	- The interviews were conducted - The digital stories were collected.

The process took 15 weeks. In this study, first of all, the TPACK-Math scale was applied as a pre-test in order to check the preservice teachers' knowledge about TPACK. Afterwards, the preservice teachers were asked to choose any of the fifth and sixth grade outcomes of the mathematics curriculum. The prospective teachers were asked to prepare a lesson plan, without any orientation, regarding the outcome they had chosen. After the lesson plans and TPACK-Math scale were collected, information about DST was given. In this process, examples were presented and in-class discussions were held. In addition, software programs that can be used in DST design were explained and examples were made on these. The preservice teachers were allowed to choose any software program they wished, and were told that they could choose a software program other than those explained in the lesson. At the end of the process, the TPACK-Math scale was applied once again, and the preservice teachers were again asked to prepare a lesson plan for the outcome they had selected at the beginning, and to fill in the structured interview form. Finally, the process was completed by collecting the designed digital stories electronically.

Data Analysis

In this study, the TPACK-Math scale was applied to the participants at two different times. Since the study group was a single group and the same scale was applied to this group at two different times, the paired samples t-test was applied for statistical analysis. Before applying this test, the assumptions required for the test were tested. Since the TPACK-Math scale has 8 different sub-dimensions in all, normality tests were conducted for each sub-dimension. Except for the Contextual Knowledge sub-dimension, all other sub-dimensions were found to have a statistically normal distribution. Since the Contextual Knowledge sub-dimension did not show a normal distribution, the non-parametric Wilcoxon signed-rank test was used in the analysis of the data belonging to this sub-dimension. The statistical significance level was set at $p<.05$. Lesson plans required from the same group before and after DST were scored with the TPACK-Based Technology Integration Assessment Rubric (Harris, Grandgenett & Hofer, 2010). There are four criteria in the rubric: Curriculum Goals and Technologies, Instructional Strategies and Technologies, Technology Selection(s), and "Fit". A one-to-four scoring is made for each criterion. These scores were analysed as pre-test and post-test. Since the scores did not show statistically normal distribution (Shapiro-Wilk=0.546, $p<.05$), analysis was made with the non-parametric Wilcoxon signed-rank test. Finally, structured interviews were conducted with the teacher candidates. The interviews were evaluated from the perspective of Yüksel-Aslan (2013).

Findings

In this section, the findings related to the sub-problems of the research are presented.
Findings regarding the change in the preservice secondary mathematics teachers before and after the DST implementation according to the TPACK-Math Scale
To determine the effect of DST on the preservice secondary mathematics teachers' TPACK, the results of the paired samples t-test for the whole scale and the eight factors are presented in Table 2.

Table 2: Results of Paired Samples t-Test for TPACK-Math scale

	Measurement	N	X	SD	T	P
TK	Pre-test	44	2.87	0.76	-4.98	0.000[a]
	Post-test	44	3.24	0.73		
PK	Pre-test	44	3.43	0.52	-4.02	0.000[a]
	Post-test	44	3.73	0.52		
CK	Pre-test	44	3.45	0.57	-4.87	0.000[a]
	Post-test	44	3.82	0.62		
TPK	Pre-test	44	3.05	0.83	-4.35	0.000[a]
	Post-test	44	3.52	0.64		
TCK	Pre-test	44	3.57	0.67	-4.73	0.000[a]
	Post-test	44	4.01	0.57		
PCK	Pre-test	44	3.27	0.56	-5.59	0.000[a]
	Post-test	44	3.75	0.61		
TPACK	Pre-test	44	3.07	0.73	-5.45	0.000[a]
	Post-test	44	3.57	0.65		
Contextual Knowledge	Pre-test	44	4.12	0.63	-7.32	0.464[b]
	Post-test	44	4.20	0.53		
Overall	Pre-test	44	3.35	0.49	-6.44	0.000[a]

TPACK-Math	Post-test	44	3.73	0.47		

Note. a=Paired samples t-test, b=Wilcoxon signed-rank test

As can be seen in Table 2, the post-test mean scores obtained by the preservice teachers from the sub-dimensions of the scale and the overall scale are higher than their pre-test mean scores. The t-test results in the table are: TK pre-test (Mean = 2.87, SD = 0.76) and post-test scores (Mean = 3.24, SD = 0.73) (t (44) = -4.98, p<.05), PK pre-test (Mean = 3.43, SD = 0.52) and post-test scores (Mean = 3.73, SD = 0.52) (t (44) = -4.02, p<.05), CK pre-test (Mean = 3.45, SD) = 0.57) and post-test scores (Mean = 3.82, SD = 0.62) (t (44) = -4.87, p<.05), TPK pre-test (Mean = 3.05, SD = 0.83) and post-test scores (Mean = 3.52, SD = 0.64) (t (44) = -4.35, p<.05), TCK pre-test (Mean = 3.57, SD = 0.67) and post-test scores (Mean = 4.01, SD = 0.57)) (t(44) = -4.73, p<.05), PCK pre-test (Mean = 3.27, SD = 0.56) and post-test scores (Mean = 3.75, SD = 0.61) (t (44) = - 5.59, p<.05) and TPACK pre-test scores (Mean= 3.07, SD = 0.73) and post-test scores (Mean= 3.57, SD = 0.65) (t(44) = -5.45, p<.05). Since the last sub-dimension of TPACK, contextual knowledge, did not show a normal distribution, the non-parametric Wilcoxon signed-rank test was used. Accordingly, the contextual knowledge pre-test scores are (Mean= 4.12, SD= 0.63) and the post-test scores are (Mean= 4.20, SD= 0.53) (z(44)= -7.32, p>.05). Considering the results of the test, there was no significant difference in the contextual knowledge sub-dimension of the TPACK-Math scale. However, a significant difference was observed in the other sub-components of the TPACK-Math scale. Finally, a significant difference was observed in the pre-test (Mean = 3.35, SD = 0.49) and post-test scores (Mean = 3.73, SD = 0.47) (t (44) = -6.44, p<.05) of the overall TPACK-Math scale. Accordingly, it can be stated that DST developed the preservice teachers' TPACK and the knowledge types belonging to the sub-components of this knowledge.

Findings regarding the change in the preservice secondary mathematics teachers' lesson plans before and after the DST implementation within the framework of TPACK

In this section, the findings related to lesson plans are discussed. When the general profile of the lesson plan findings is examined, it is seen that the preservice teachers who chose outcomes related to geometry used technology. It is seen that only a few of the teacher candidates who chose outcomes related to algebra used smartboards and the Educational Information Network (EBA). The contents of the lesson plans prepared by the teacher candidates before and after the digital story design were scored with the aid of the TPACK-Based Technology Integration Assessment Rubric developed by Harris, Grandgenett and Hofer (2010). By calculating the total score obtained by each preservice teacher, the lesson plans prepared before and after the design were specified as pre-test and post-test. Since these determined scores did not show statistically normal distribution (Shapiro-Wilk = 0.546, p<.05), the non-parametric Wilcoxon signed-rank test was applied to the obtained pre- and post-test scores to examine the effect of the students' lesson plans on their TPACK. The results of the pre-test and post-test scores obtained by the preservice teachers for the lesson plans according to their TPACK skills are given in Table 3.

Table 3: Wilcoxon Signed-Rank Test Results for Lesson Plans

	Measurement	N	X	SD	Z	P
Lesson Plan	Pre-test	44	5.61	3.25	-5.65	.000
	Post-test	44	10.84	3.70		

By examining Table 3, it can be seen that there is a significant difference between the pre-test (Mean = 5.61, SD = 3.25) and post-test scores (Mean = 10.84, SD = 3.70) for the lesson plans prepared by the teacher candidates. This shows that DST made a positive contribution to their TPACK in lesson plans.

Findings regarding the stage at which the preservice secondary mathematics teachers felt most comfortable in the DST process according to the TPACK framework

The data regarding the stage at which the participants felt most comfortable in the DST process were analysed and are presented in Table 4:

Table 4 : Frequency and percentage table for data regarding the stage at which preservice teachers felt most comfortable in the DST process

Components	f	%
TK (Using the Software)	16	36
CK (Choosing the Topic)	14	32
PK (Choosing the Message)	11	25
PCK (Creating the Script)	9	20
TCK (Creating the Storyboard)	7	16
TPACK (Combining the elements)	6	14
TPK (Choosing the Material)	5	11

When the answers given by the preservice teachers are examined, it is seen that while designing digital stories, they felt most comfortable in using the software, choosing the topic and choosing the message. This shows that in digital story design, the teacher candidates did not have difficulty in TK, associated with using the software, CK, associated with choosing the topic, and PK, associated with choosing the message.

Findings regarding the stage at which the preservice secondary mathematics teachers had difficulty in the DST process according to the TPACK framework

The data regarding the stage at which the participants had difficulty in the DST process were analysed and are presented in Table 5:

Table 5 : Frequency and percentage table for data regarding the stage at which the candidates had difficulty in the DST Process

Components	f	%
PCK (Creating the Script)	29	66
TK (Using the Software)	25	57
TPACK (Combining the elements)	16	36
TCK (Creating the Storyboard)	7	16
PK (Choosing the Message)	6	14
CK (Choosing the Topic)	2	5

When the answers given by the candidates are examined, it can be seen that while designing a digital story, they had more difficulty in creating the script, using the software and combining the elements. This shows that in digital story design, the candidates had difficulties in PCK, associated with creating the script, TK, associated with using the software, and TPACK, associated with combining the elements.

CONCLUSIONS

As a teaching tool, DST can improve understanding of TPACK. The interaction of the six elements, TK, PK, CK, TPK, TCK, and PCK, assists in selecting knowledge in a more strategic and diverse way (Clarke, 2017). Coutinho (2010) stated that DST is a powerful tool to use in the field of technology and teacher education because it allows teachers to mobilise their multiple knowledge about the curriculum, pedagogy and technology. Although this is also the case for preservice teachers, Harriman (2011) emphasised the necessity of conducting more research.

Considering the results of this study, it was seen that there was a significant difference between the pre-test and post-test scores in seven knowledge types in the TPACK-Math scale. However, it was determined that there was no significant change in contextual knowledge. While defining PCK, Shulman (1987) also explained contextual knowledge as one of the components of PCK. Grossman (1990) stated that contextual knowledge is the knowledge that the teachers should have about the student, school, society and the country in which they live (Şen & Öztekin, 2019). Moreover, in his research, Mishra (2019) added contextual knowledge to the TPACK framework. Therefore, this type of knowledge is considered to be important. For this reason, it was considered important to include contextual knowledge questions in the scale that was used as a pre-test and post-test in this study. However, a significant result could not be obtained for this type of knowledge. According to the data obtained from the scale, it was concluded that DST-assisted instruction had a positive effect on the development of the preservice teachers' TPACK. In her study, Wang (2016) worked with two groups and gave DST-assisted instruction to the experimental group. The results of the study are in line with those of this study. However, in her research, Harriman (2011) stated that there was a slight change in TK in the TPACK survey. Sancar-Tokmak and Yanpar-Yelken (2015), on the other hand, stated that there were positive significant differences between TPACK self-confidence scores before and after creating digital stories. They stated that especially the TPK and TK scores showed a significant change with the assistance of DST. However, there was no significant change in TCK. Wen and Shinas (2020) stated that there were significant positive changes in all areas except PK, while the survey results alone were inconsistent with the other data collection tools. In this research, the use of a TPACK scale for mathematics distinguishes the study from other studies.

The teacher candidates' projection onto their lesson plans of their skills in implementing educational technologies is a sign of increasing TPACK (Kurt et al., 2014; Zimmermann et al., 2021). When the lesson plans prepared by the preservice teachers before and after the DST process were analysed, it was evident that there was an improvement in their TPACK. Although she worked with teachers, the results of this research are similar to those of Dewi (2016). Similarly, Canbazoğlu-Bilici, Guzey and Yamak (2016) analysed lesson plans with the rubric developed by Lyublinskaya and Tournaki (2011) and revealed that participants' TPACK scores increased significantly, reaching the second of the five TPACK levels on average. Furthermore, Akyüz (2018), Crosthwaite, Luciana and Wijaya (2021), Kapıcı and Akçay (2020) and Kwagsawad (2016) also stated that there was an improvement in lesson plans in their research.

The structured interview questions were analysed with the TPACK diagram (Yüksel-Aslan, 2013). When the TPACK diagram findings were examined, it was seen that the teacher candidates felt most comfortable in using the software (TC). This was followed by choosing the topic (CK) and choosing the message (PK), respectively. However, it was determined that the preservice teachers did not feel very comfortable in TPACK, that is, in combining the elements. It was observed that the preservice teachers had the most difficulty in creating the script (PCK), using the software (TK) and combining the elements (TPACK), respectively. From this point of view, it can be thought that the preservice teachers were unable to fully access TPACK in this process. In their research, Sancar-Tokmak et al. (2014) applied the TPACK diagram at the beginning and end of the study. As a result of the study, they stated that preservice teachers did not initially have adequate CK and PCK. Similarly, Kildan and İncikabı (2015) applied the TPACK diagram at the beginning and end of their study. Accordingly, it was determined that there was an increase in participants' TPACK. In this study, based on the knowledge that the preservice teachers had not previously designed digital stories, no implementation was made at the beginning of the process.

Studies exist in the literature in which DST has a positive effect on preservice teachers' TPACK (Dewi, 2016; Harriman & Branch, 2012; Wah, 2018; Kılıç et al., 2019; Kildan & İncikabı, 2015; Sancar-Tokmak et al., 2014; Sancar-Tokmak & Yanpar-Yelken, 2015). Similarly, in this study, it was observed that the DST method had a positive effect on TPACK development in preservice secondary mathematics teachers.

REFERENCES

1. Aksüt, P., & Aydin, F. (2021). Creating digital stories: a case study of Turkish preschool environmental education. ie: Inquiry in Education, 13(2), 1-18.
2. Akyüz, D. (2018). Measuring technological pedagogical content knowledge (TPACK) through performance assessment. Computers & Education, 125, 212-225. https://doi.org/10.1016/j.compedu.2018.06.012
3. Alabbasi, D. (2018). The design and application of a digital storytelling process model to enhance teachers' understanding of TPACK and foster positive attitudes toward teaching with technologies. International Journal of Technology Enhanced Learning, 10(4), 309-328.
4. Albano, G., & Pierri, A. (2017). Digital storytelling in mathematics: a competence-based methodology. Journal of Ambient Intelligence and Humanized Computing, 8(2), 301-312. https://doi.org/10.1007/s12652-016-0398-8
5. Albano, G., Iacono, U. D., & Fiorentino, G. (2020). A technological storytelling approach to nurture mathematical argumentation. In Proceedings of the 12th International Conference on Computer Supported Education (CSEDU 2020), 1, 420-427.
6. Albano, G., Pierri, A. (2014). Mathematical competencies in a role-play activity. In Nicol,C.,Liljedhak, P., Oesterle, S.& Allan,D.(Eds.). Proc. 38th Conf. of the Int. Group for the Psychology of Mathematics Education (Vol.2, pp.17-24). Vancouver, Canada: PME.
7. Amelia, P., Rukmini, D., Mujiyanto, J., & Bharati, D. A. L. (2021). Investigating the development of teachers' tpack and the adoption of digital storytelling: A case study of teaching english in elementary school. The Journal of AsiaTEFL, 18(2), 701-710.

8. Archambault, L. M., & Barnett, J. H. (2010). Revisiting technological pedagogical content knowledge: Exploring the TPACK framework. Computers & Education, 55(4), 1656-1662. https://doi.org/10.1016/j.compedu.2010.07.009
9. Barrett, H. (2006, March). Researching and evaluating digital storytelling as a deep learning tool. In Society for Information Technology & Teacher Education International Conference (pp. 647-654). Association for the Advancement of Computing in Education (AACE).
10. Büyükkarcı, A., & Müldür, M. (2022). Digital storytelling for primary school mathematics teaching: product and process evaluation. Education and Information Technologies, 1-32. https://doi.org/10.1007/s10639-021-10813-8
11. Çakıcı, L. (2018). The effect of digital story based teaching on mathematics of student's academic achievement motivation and attitude towards mathematical activities. [Unpublished masters thesis]. Gaziantep University.
12. Canbazoglu-Bilici, S., Guzey, S. S., & Yamak, H. (2016). Assessing pre-service science teachers' technological pedagogical content knowledge (TPACK) through observations and lesson plans. Research in Science & Technological Education, 34(2), 237-251. https://doi.org/10.1080/02635143.2016.1144050
13. Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2010). Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK). Journal of Educational Technology & Society, 13(4), 63-73.
14. Clarke, A. M. (2017). A place for digital storytelling in teacher pedagogy. Universal Journal of Educational Research, 5(11), 2045-2055. DOI: 10.13189/ujer.2017.051121
15. Crosthwaite, P., Luciana, & Wijaya, D. (2021). Exploring language teachers' lesson planning for corpus-based language teaching: a focus on developing TPACK for corpora and DDL. Computer Assisted Language Learning, 1-29. https://doi.org/10.1080/09588221.2021.1995001
16. De Rossi, M., & Restiglian, E. (2019). Hybrid solutions for didactics in higher education: An interdisciplinary workshop of 'Visual Storytelling'to develop documentation competences. Tuning Journal for Higher Education, 6(2), 175-203. https://doi.org/10.18543/tjhe-6(2)-2019pp175-203
17. Dewi, F. (2016). Digital storytelling project: an alternative to develop English teachers' technological pedagogical and content knowledge (TPACK). SPaCe Edu Journal, 2(1), 16-40.
18. Di Blas, N. (2016). Distributed TPACK What kind of teachers does it work for?. Journal of e-Learning and Knowledge Society, 12(3), 65-74.
19. Dinçer, B. (2019). The effects of the digital story-based mathematics teaching on concept learning of secondary school students. [Unpublished doctoral dissertation]. Dokuz Eylül University.
20. Graham, C. R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). Computers & Education, 57(3), 1953-1960. https://doi.org/10.1016/j.compedu.2011.04.010
21. Harriman, C. L. S., & Branch, R. M. (2012). Aligning digital storytelling to the TPACK framework: A learning experience for pre-service teachers in a learning-by-designing project. In Anais do Workshop de Informática na Escola, 18(1), 20-29.
22. Harris, J., Grandgenett, N., & Hofer, M. (2010, March). Testing a TPACK-based technology integration assessment rubric. In Society for Information Technology & Teacher Education International Conference (pp. 3833-3840). Association for the Advancement of Computing in Education (AACE).
23. Hicks, T., Turner, K., & Stratton, J. (2013). Reimagining a writer's process through digital storytelling. Learning Landscapes, 6(2), 167-183. https://doi.org/10.36510/learnland.v6i2.611
24. İnan, C. (2015). A digital storytelling study project on mathematics course with preschool pre-service teachers. Educational Research and Reviews, 10(10), 1476-1479. https://doi.org/10.5897/ERR2015.2247
25. Istenic Starčič, A., Cotic, M., Solomonides, I., & Volk, M. (2016). Engaging preservice primary and preprimary school teachers in digital storytelling for the teaching and learning of mathematics. British Journal of Educational Technology, 47(1), 29-50. https://doi.org/10.1111/bjet.12253
26. Kapici, H. O., & Akcay, H. (2020). Improving student teachers' TPACK self-efficacy through lesson planning practice in the virtual platform. Educational Studies, 1-23. https://doi.org/10.1080/03055698.2020.1835610

27. Karaoğlan-Yılmaz, F. G., Özdemir, B. G., & Yasar, Z. (2018). Using digital stories to reduce misconceptions and mistakes about fractions: an action study. International Journal of Mathematical Education in Science and Technology, 49(6), 867-898. https://doi.org/10.1080/0020739X.2017.1418919
28. Kildan, A. O., & Incikabi, L. (2015). Effects on the technological pedagogical content knowledge of early childhood teacher candidates using digital storytelling to teach mathematics. Education 3-13, 43(3), 238-248. https://doi.org/10.1080/03004279.2013.804852
29. Koehler, M. J., Shin, T. S., & Mishra, P. (2012). How do we measure TPACK? Let me count the ways. In Educational technology, teacher knowledge, and classroom impact: A research handbook on frameworks and approaches (pp. 16–31). Hershey, PA: IGI Global.
30. Kordaki, M., & Kakavas, P. (2017). Digital storytelling as an effective framework for the development of computational thinking skills. In EDULEARN2017, 3-5 July, 2017.
31. Kurt, G., Akyel, A., Koçoğlu, Z., & Mishra, P. (2014). TPACK in practice: A qualitative study on technology integrated lesson planning and implementation of Turkish pre-service teachers of English. ELT Research Journal, 3(3), 153-166.
32. Kwangsawad, T. (2016). Examining EFL pre-service teachers' TPACK trough self-report, lesson plans and actual practice. Journal of Education and Learning, 10(2), 103-108.
33. Lisenbee, P. S., & Ford, C. M. (2018). Engaging students in traditional and digital storytelling to make connections between pedagogy and children’s experiences. Early Childhood Education Journal, 46(1), 129-139. https://doi.org/10.1007/s10643-017-0846-x
34. Lyublinskaya, I., & Kaplon-Schilis, A. (2022). Analysis of differences in the levels of tpack: unpacking performance ındicators in the tpack levels rubric. Education Sciences, 12(2), 79. https://doi.org/10.3390/educsci12020079
35. McGraw-Hill Education. (2020). What is TPACK theory and how can it be used in the classroom? Toronto, ON: Author. Retrieved from 39 https://www.mheducation.ca/blog/what-is-tpack-theory-and-how-can-it-be-used-in-theclassroom/
36. McLellan, H. (2007). Digital storytelling in higher education. Journal of Computing in Higher Education, 19(1), 65-79. https://doi.org/10.1007/BF03033420
37. Ministry of National Education (2018). Mathematics lesson curriculum (Primary and secondary school 1, 2, 3, 4, 5, 6, 7 and 8th Grades). MoNE Publications.
38. Mishra, P. & Koehler, M.J. (2006). Technological pedagogical content knowledge: a framework for teacher knowledge. Teachers College Record, 108(6), 1017-1054.
39. Nerurkar, O. (2020). Digital Story Telling using TPACK Model: A Case. Annual Research Journal of SCMS, Pune Volume 8, 29-34.
40. Niemi, H., Shuanghong, N. İ. U., Vivitsou, M., & Baoping, L. İ. (2018). Digital storytelling for twenty-first-century competencies with math literacy and student engagement in China and Finland. Contemporary Educational Technology, 9(4), 331-353. https://doi.org/10.30935/cet.470999
41. Niess, M. L., Ronau, R. N., Shafer, K. G., Driskell, S. O., Harper, S. R., Johnston, C.,Browning, C. , Özgün- Koca, S., A. & Kersaint, G. (2009). Mathematics teacher TPACK standards and development model. Contemporary Issues in Technology and Teacher Education, 9(1), 4-24.
42. Ohler, J. (2006). The world of digital storytelling. Educational Leadership, 63(4), 44-47.
43. Önal, N. (2016). Development, validity and reliability of TPACK scale with pre-service mathematics teachers. International Online Journal of Educational Sciences, 8(2), 93-107.
44. Özpinar, İ., Gökçe, S., & Yenmez, A. A. (2017). Effects of digital storytelling in mathematics ınstruction on academic achievement and examination of teacher-student opinions on the process. Journal of Education and Training Studies, 5(10), 137-149. https://doi.org/10.11114/jets.v5i10.2595
45. Preradovic, N. M., Lesin, G., & Boras, D. (2016). Introduction of digital storytelling in preschool education: A case study from Croatia. Digital Education Review, 94-105. https://doi.org/10.1344/der.2016.30.94-105
46. Robin, B. R. (2015). Handbook of research on teaching literacy through the communicative and visual arts,Flood, J. ,Heath, S. B. & Lapp, D. (Eds.), The effective uses of digital storytelling as a teaching and learning tool (pp.429-440).Routledge.
47. Robin, B. R. (2016). The power of digital storytelling to support teaching and learning. Digital Education Review, (30), 17-29.

48. Sancar-Tokmak, H., & Yanpar-Yelken, T. (2015). Effects of creating digital stories on foreign language education pre-service teachers' TPACK self-confidence. Educational Studies, 41(4), 444-461. https://doi.org/10.1080/03055698.2015.1043978
49. Schmid, M., Brianza, E., & Petko, D. (2021). Self-reported technological pedagogical content knowledge (TPACK) of pre-service teachers in relation to digital technology use in lesson plans. Computers in Human Behavior, 115, 106586. https://doi.org/10.1016/j.chb.2020.106586
50. Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK) the development and validation of an assessment instrument for preservice teachers. Journal of Research on Technology in Education, 42(2), 123-149. https://doi.org/10.1080/15391523.2009.10782544
51. Şen, M., & Öztekin, C. (2019). Interaction among contextual knowledge and pedagogical content knowledge: sociocultural perspective. Education and Science, 44(198), 57-97. http://dx.doi.org/10.15390/EB.2019.7927
52. Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. Harvard Educational Review, 57(1), 1-23.
53. Tashakkori, A., Teddlie, C., & Johnson, B. (2015). Mixed methods.
54. Teaching and Learning International Survey (TALİS), (2018). TALIS 2018 Results and Evaluations on Turkey, TedMem. https://tedmem.org/download/talis-2018-sonuclari-turkiye-uzerine degerlendirmeler?wpdmdl=3085&refresh=624ed7d25fd851649334226
55. Van Gils, F. (2005, June). Potential applications of digital storytelling in education. In 3rd Twente Student Conference on IT (Vol. 7, No. 7). University of Twente, Faculty of Electrical Engineering, Mathematics and Computer Science Enschede.
56. Wah, L. K. (2018). Developing ın-service esl teachers' tpack to teach in the 21st century. Advanced Science Letters, 24(1), 230-232. https://doi.org/10.1166/asl.2018.11968
57. Walters, L., Green, M., Goldsby, D., & Parker, D. (2018). Digital storytelling as a problem-solving strategy in mathematics teacher education: How making a math-eo engages and excites 21st century students. International Journal of Technology in Education and Science, 2(1), 1-16.
58. Wang, A. Y. (2016). The handbook of technological pedagogical content knowledge (TPACK) for educators, Herring, C., M. ,Koehler, M., J., & Mishra, P. (Eds.),The impact of digital storytelling on the development of TPACK among student teachers in Taiwan (pp 297-308). Routledge.
59. Wen, H., & Shinas, V. H. (2020). Using a multidimensional approach to examine TPACK among teacher candidates. Journal of Digital Learning in Teacher Education, 37(1), 30-47. https://doi.org/10.1080/21532974.2020.1804493
60. Yang, Y. T. C., & Wu, W. C. I. (2012). Digital storytelling for enhancing student academic achievement, critical thinking, and learning motivation: A year-long experimental study. Computers & Education, 59(2), 339-352. https://doi.org/10.1016/j.compedu.2011.12.012
61. Yurdakul, I. K., Odabasi, H. F., Sahin, Y. L., & Coklar, A. N. (2013). A TPACK course for developing pre-service teachers' technology integration competencies: from design and application to evaluation. In Research perspectives and best practices in educational technology integration (pp. 242-269). IGI Global.
62. Zimmermann, F., Melle, I., & Huwer, J. (2021). Developing prospective chemistry teachers' tpack–a comparison between students of two different universities and expertise levels regarding their tpack self-efficacy, attitude, and lesson planning competence. Journal of Chemical Education, 98(6), 1863-1874. https://doi.org/10.1021/acs.jchemed.0c01296