# Using Digital Storytelling to Enhance the Pedagogical Content Knowledge of Prospective Secondary School Mathematics Teachers

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This research analyzed the effect of digital storytelling (DST) on the development of prospective secondary school mathematics teachers' pedagogical content knowledge (PCK) regarding students' algebraic mistakes. The research applied sub-domains of PCK, the knowledge of content and students (KCS), and the knowledge of content and teaching (KCT). A mixed research design, Explanatory Sequential Design, was employed in parallel with the research objectives. The research participants were 52 prospective teachers enrolled as students at a Turkish university's undergraduate school of education. In DST practices, each prospective teacher developed a digital story on a mistake in algebra. Quantitative data were collected via a knowledge test composed of ten open-ended scenarios, whereas qualitative data were acquired through a structured interview form. Quantitative data were analyzed with a non-parametric hypothesis test, Wilcoxon Signed-Rank Test, while qualitative data were examined with content analysis. At the end of the research, there was a statistically significant development in KCS and KCT levels of prospective teachers for algebra. Moreover, prospective teachers generally provided positive feedback on digital storytelling.

## Introduction

Upon the analysis of the historical background of math teaching, it was observed that the primary focus of most math teachers was to ensure that their students solved arithmetic operations quickly and smoothly (Romberg & Kaput, 1999). However, this approach is no longer sufficient for developing the human profile sought by today's societies (Chimoni et al., 2018). Henceforth, students are expected to understand more complex mathematical structures, comprehend the relationship between them and their living conditions, and express these relationships in mathematical terms (Ministry of National Education [MoNE], 2018). Meeting these expectations will only be possible if students have a good command of algebra and arithmetic (Blanton & Kaput, 2005). Many factors make algebra crucial in the teaching of mathematics.

It is possible to solve complex problems through algebra through a smaller number of operations (Ususkin, 1995). For instance, in solving a problem such as "What would be the number of handshakes in a meeting of a hundred persons?" it will be very exhausting to calculate handshakes for each group member of a group of size 100. However, it is plausible instead to calculate the number of handshakes if only 2 or 3 or 4 persons participate in the meeting, and then make a generalization around this relatively simple calculation and express this generalization with the following algebraic expression, $\left(\frac{(n-1).n}{2}\right)$ (Blanton & Kaput, 2005). Algebra makes it possible to pronounce verbal expressions briefly as symbols, letters, and variables. In other words, algebra makes math more economical.

Mathematicians began to work out problems, proofs, and operations faster and with alternative scenarios thanks to algebra. That being the case, algebra accelerated positive developments in mathematics (Lannin, 2005). On the one hand, while algebra's symbolism and abstract structure make it valuable for mathematicians, they may seriously challenge students (Blanton & Kaput, 2005). Most previous studies deduced that students faced specific difficulties in learning algebra concepts (Arcavi, 1995; McNeil & Alibali, 2005; Şahin & Soylu, 2011). Reducing the variable to a single value in algebra operations (Arcavi, 1995; MacGregor & Stacey, 1997), reverse assignment of coefficients to variables (Clement, 1982), generalizing the rule for eliminating the constant to the elimination of coefficient in the solution of an equation (Jupri & Drijvers, 2016), failure to convert verbal expressions into algebraic terms (Şahin & Soylu, 2011), and failure to draw the correct graph corresponding to a given equation (Greenes et al., 2007) are among mistakes made by students.

For securing a meaningful learning experience and for overcoming learning challenges of students in the process of algebra education, the most important duty and responsibility fall upon teachers as previous studies indicated that math teaching skills of teachers occupied a significant place in the learning of math by students (Tchoshanov et al., 2017). Several studies were performed to describe the occupational knowledge and experiences that teachers should possess. Such studies are still pioneered by the pedagogical content knowledge (PCK) model introduced by Shulman (1986). This model asserts that, for a person to teach physics, chemistry, geography, or math, having only a theoretical knowledge base in these areas is not satisfactory. However, the person must also know the most effective ways of transferring his/her knowledge to students (Shulman, 1986, 1987). Thus, PCK is a concept that distinguishes a content specialist from a teacher (Shulman, 1987). Shulman (1986) described occupational knowledge and skills specific to the teaching profession through the PCK model. Afterward, researchers inspired by Shulman's model (1986) developed discipline-specific models peculiar to math, physics, etc. (Park & Oliver, 2008). Among the models developed in mathematics, the model developed by Ball, Thames, and Phelps (2008) comes to the forefront. Ball, Thames, and Phelps's (2008) model argues that the occupational knowledge base that a teacher should possess is categorized into two main parts: subject matter knowledge and pedagogical content knowledge. In this model, PCK is composed of (i) knowledge of content and students, (ii) knowledge of content and teaching, and (iii) knowledge of content and curriculum.

Several studies identified the PCK level of math and prospective math teachers in the literature. Most studies (Şahin et al., 2016; Tirosh, 2000) deduced that PCK levels of teachers and prospective teachers concerning math teaching were unsatisfactory. In this regard, researchers attempted to apply various methods to enhance the PCK levels of teachers and prospective teachers (Depaepe et al., 2013). Case-based studies (Lin, 2005), structured interviews (Jenkins, 2010), coaching (Stewart, 2013), microteaching (Hadfield et al., 1998), lesson study (Baki, 2012), microteaching lesson study (Fernandez, 2010), teaching experiment (Chamberlin & Candelaria, 2018), vignette (Hauk et al., 2013) and alternative occupational knowledge development programs designed by researchers (Lannin et al., 2013) are among these methods. However, today, when technological advancements are highly intertwined with life, enough studies conducted on the effect of computer technologies on the development of PCK levels of teachers and prospective teachers do not exist. In this context, this study utilized one of today's technologies to develop prospective teachers' pedagogical content knowledge of algebra, namely, digital stories. Research questions to be addressed given the objectives of this study are noted below:

1) Did DST have a statistically significant effect on the development of PCK levels of prospective math teachers?
    a) Did DST have a statistically significant effect on the development of KCS?
    b) Did DST have a statistically significant effect on the development of KCT?
2) What are the views of prospective math teachers on DST?

*Mistakes/Misconceptions in Algebra*

Quite a few studies reported that students were troubled by different difficulties during the algebra learning process (Arcavi, 1995; McNeil & Alibali, 2005). Algebra becomes even more challenging for students facing algebra for the first time in the transition process from concrete to abstract operations (Tall & Thomas, 1991).

A common mistake students make in algebra learning is the inclination to substitute a value for the variable (Arcavi, 1995; McNeil & Alibali, 2005). In the study by MacGregor and Stacey (1997), students were asked to answer the following question: "*David is 10 cm taller than John. John is h cm tall. What can you write for David's height?*" It was observed that, of 14 students participating in the study, five students attempted to substitute specific values for John's height rather than write an algebraic equation to find David's height.

Another mistake made in algebra by students at different levels of education is incorrectly writing algebra expressions, equations, or inequalities while converting verbal expressions into algebraic form (Clement, 1982; MacGregor & Stacey, 1997; Şahin & Soylu, 2011). Students make such mistakes as the failure to use parenthesis or incorrect use of parenthesis (Şahin & Soylu, 2011) and incorrect assignment of coefficients to variables (Clement, 1982). For example, Şahin & Soylu (2011) asked the $7^{th}$-grade students the following question: *"Please sum unknown n with five and then multiply the result with 3."* In this context, certain students failed to write $3(n+5)$ and formulated the algebraic expression incorrectly as $n = 5 \cdot 3$. Similarly, Clement (1982) asked the students to formulate an equation for the following: "*There are six times as many students as professors at this university. Use S for the number of students and P for the number of professors.*" Certain students formulated the equation as $6S = P$ by assigning 6 as the coefficient for students and 1 as the coefficient for professors who were outnumbered by students in this case. In other words, these students assigned coefficients inversely. Likewise, Sleeman (1984) alleged that certain students attributed the same meaning to the following algebraic expressions: $3 + x$ and $3x$.

Moreover, certain misconceptions reported in the relevant literature are related to difficulties students encounter in solving equations (Carry, Lewis, & Bernard, 1980; Ekenstam & Nilsson, 1979; Jupri & Drijvers, 2016). The study performed by Ekenstam and Nilsson (1979) suggested that students had more trouble in solving equations when the variable was in denominator $\left(\frac{2}{x} = \frac{3}{2}\right)$ than the solution of equations when the variable was in the numerator $\left(\frac{x}{6} = \frac{2}{9}\right)$. Additionally, students were not challenged by equations if the value of a variable was supposed to be a whole number $(6x = 12)$ whereas they did not feel at ease if the value of a variable was assumed to be a rational number $(243x = 242)$. Carry et al. (1980) observed in their study that, in the solution of the equation, $9(x+40) = 5(x+40)$, certain students reached the result, $9 = 5$, by eliminating simultaneously the expression in parentheses, $x + 40$, from both sides of the equation as if to simplify the equation. In the same study, certain students, as if simplifying, eliminated simultaneously the exponent on the left side of the equation and the coefficient on the right side of the equation, $x^2 = 2x$, and found the unknown represented by $x$ as $2(x = 2)$. Certain students reached the solution, $x = 1 - 4$, upon solving the equation, $4x = 1$, because of incorrectly applying the method for eliminating constant to the elimination of coefficient.

Another concept challenging for students in the algebra learning process is the slope (Cho & Nagle, 2017). It was alleged that students had general knowledge about slope operations. However, their conceptual knowledge of the slope was unsatisfactory (Cho &

Nagle, 2017; Li, 2006). In the study by Li (2006), students with a low level of achievement could predict the increase in $y$ variable based upon the slope if $x$ variable was increased by 1 in the equation, $y = 2x + 5$. However, they did not prefer drawing a table to understand the relationship between two variables better. Therefore, students will likely make mistakes if the equation is presented in an unfamiliar format different from $y = mx + n$. Greenes et al. (2007) asserted that high school students had trouble finding the slope of an equation or linear graph and drawing the linear graph. For instance, students found the sign of a slope incorrectly on account of ignoring the line direction when calculating the slope of a line. Other mistakes made about slope are reported in the literature, as confusion over what each letter represents in equation $y = mx + n$, failure to find the slope of a line whose two points are given, presuming that the slope pertains to height or angle, deciding whether $x$ variable will be over $y$ variable or $y$ variable will be over $x$ variable in the calculation of slope (Teuscher & Reys, 2010).

Although the subject of inequalities is taught in high schools in quite a few countries, inequalities are first introduced in secondary schools in certain countries, and this subject is among the concepts deemed quite difficult, especially for secondary school students to understand (Almog & Ilany, 2012). In the solution of an inequality such as $(x - 2)(x + 5) \geq 0$, students in general, prefer to divide the inequality into two parts as $(x - 2) \geq 0$ and $(x + 5) \geq 0$. Afterward, they present an answer upon solving these two parts of inequality independently of each other (Kroll, 1986). On the other hand, certain students apply the same rules they learn for solving equations to the solution of inequalities. (Kroll, 1986; Tsamir et al., 1998). For example, in the inequality solution, $-2x < 66$, certain students find the solution set as $x < -3$ by dividing both sides of inequality by $(-2)$ (Kroll, 1986). Likewise, in the solution of an inequality such as $\frac{2x-2}{x+1} < 1$, certain students employ cross-multiplication as in the case of the solution of an equation and tend to neglect to pay attention to variable values which will make the denominator equal to zero (Tsamir et al., 1998).

*Pedagogical Content Knowledge (PCK)*

The concept of '*Pedagogical Content Knowledge'* (PCK) was introduced to the literature for the first time by Shulman (1986) to identify the occupational knowledge and skills that teachers should possess (Depaepe et al., 2013). Shulman addressed problems about teacher education as *'missing paradigm'* and described the PCK as a quest for finding a solution to such problems (Depaepe et al., 2013). Although Shulman (1986) emphasized content knowledge, he suggested that a content specialist and a teacher had different knowledge bases and skills (Cochran, De Ruiter, & King, 1993). Shulman (1987) addressed occupational knowledge essential for the teaching profession under seven categories, including pedagogical content knowledge. Other six categories are content knowledge, general pedagogical knowledge, curriculum knowledge, knowledge of learners and their characteristics, knowledge of educational contexts, knowledge of educational ends, purposes, and values, and their philosophical and historical background (Shulman, 1987, p. 8).

Rather than being specific to a discipline, Shulman's (1986, 1987) studies offered a general description of occupational knowledge and skills essential for the teaching profession. Other researchers from various disciplines influenced by Shulman's (1987) views attempted to describe professional knowledge and skills specific to their disciplines (Depaepe et al., 2013; Park & Oliver, 2008). In this framework, PCK models were developed to describe professional knowledge and skills that a math teacher should possess (An, Kulm, & Wu, 2004; Ball, Thames & Phelps, 2008; Carrillo-Yañez et al., 2018; Ma, 1999). Of these models, the mathematical knowledge for teaching (MKT) model by Ball et al. (2008) comes to the forefront. Ball et al. (2008) developed this model firstly by arguing that Shulman's (1987) PCK model was far from being satisfactory because it was too general, lacked empirical foundation, and failed to describe PCK clearly and secondly by highlighting the need to create a model purely specific to math and with a strong empirical foundation. MKT describes the knowledge base needed by a teacher to lecture math effectively to students (Depaepe et al., 2013). The MKT model (Ball et al., 2008) comprises two main parts: subject matter knowledge and pedagogical content knowledge. The key features of this model distinguishing it from other PCK models are (i) the fact that subject matter knowledge has subdomains and (ii) the fact that it puts particular emphasis on content knowledge while addressing sub-domains of pedagogical content knowledge (Carrillo-Yañez et al., 2018).

Ball et al. (2008) expanded the framework set by Shulman (1987) rather than applying a different approach to the MKT model. Shulman's PCK model (1987) had two sub-domains, 'knowledge of teaching strategies and representations' and 'knowledge of understanding student's (mis)conceptions' (Depaepe et al., 2013). However, Ball et al. (2008) introduced the 'knowledge of content and curriculum' sub-domain as part of PCK in addition to these two sub-domains. Shulman (1987) considered knowledge of curriculum as a category separate from PCK. Additionally, Ball et al. (2008) put particular emphasis on content knowledge while addressing sub-domains of PCK. '*Knowledge of content and students* (KCS)' and '*Knowledge of content and teaching* (KCT)' were included in the conceptual framework of the current research because the current research portrayed mistakes of secondary school students on algebra and addressed skills essential for making teaching clarifications to correct such mistakes.

KCS pertains to the math teacher's knowledge regarding what students know and think about math concepts, what topics students are interested in, how students will be motivated, what topics challenge students, and what type of mistakes students make (Ball et al., 2008; Carrillo-Yañez et al., 2018). KCT relates to various aspects of the math teaching process, such as examples that teachers should start teaching with, methods and techniques that teachers should apply, acquaintance with the introduction of concepts in different ways, proper math assignments to be given to students, and responses intended for misconceptions of students (Ball et al., 2008). KCT is about effectively lecturing students about math concepts and requires both math and pedagogical knowledge (Depaepe et al., 2013). Shulman (1987) addressed two dimensions of KCT: responses intended for misconceptions and concept teaching (Depaepe et al., 2013). If a math teacher is faced with a student mistake in the context of the MKT model, he/she is supposed to define the mistake, question the basis of the mistake, and know what he/she is supposed to do in order to ensure that the student is likely to avoid making a mistake again in the future (Ball et al., 2008; Carrillo-Yañez et al., 2018). That being the case, the current study used DST so that prospective teachers could deal with student mistakes and develop responding techniques intended for these mistakes.

*Digital Storytelling*

Along with fast technological advancements, it became inevitable to frequently use data communication technologies (Yang & Wu, 2012). Students need media-varied environments in today's classrooms to configure their learning experiences (Riesland, 2005). Storytelling is one of those technologies designed to meet these needs (Robin & Pierson, 2005). There are different definitions for DST. However, it can be defined as digital storytelling using images, audio, and video (Robin, 2005). Porter (2005) defined DST as a person's narration of a story by combining his/her voice with technological instruments such as images, graphics, music, and sound of his/her own choice and superseding the old art of verbal storytelling.

Researchers characterize phases of the DST process based on different approaches. In the study conducted by Sancar-Tokmak and Yanpar-Yelken (2015) to analyze the development of prospective English teachers' technological pedagogical content knowledge (TPACK), the DST process comprises seven phases. The following are these phases: Selecting a topic, Message selection, Scenario writing, Digital material selection, Storyboard creation, Software use, and Evaluation of digital story. Kearney (2011), however, addressed DST in nine consecutive phases, Developing ideas, Storyboard/scripting, Re-storyboarding, Preparation for filming, Filming, Editing, Small-group viewing, General class/school presentation, Dissemination-publication. By and large, DST can be summarized in four phases the Pre-Production Phase in which story topics and messages are specified and scenarios are written, the phase in which digital materials are prepared; the Post-production Phase, in which digital materials are produced for different scenarios were combined and Distribution Phase in which the digital story production was watched and assessed (Porter, 2005).

Quite a few studies were performed on applying DST to education with different objectives. In these studies, researchers applied digital stories produced generally in three different ways. First is the use of previously prepared stories, second is the use of stories to be created by the teacher for his/her purpose, and third is the use of stories prepared by students (Robin, 2008). Karaoglan Yilmaz et al. (2018) deduced that the digital stories they prepared in line with the purpose of their research were effective in correcting secondary school students' misconceptions about fractions. Sarıca and Usluel (2016) suggested that DST positively influenced the development of visual memory and writing skills of primary school students. Heo (2009) asserted that DST improved the self-competency of prospective teachers in educational technology. It is observed that studies on DST targeted primarily students (Karaoglan Yilmaz et al., 2018; Sarıca & Usluel, 2016), and there was a relatively limited number of studies intended for teachers and prospective teachers (Heo, 2009). That being the case, the current research focused on studying the effect of DST on the development of PCK in the algebra of prospective math teachers.

## Method

The current study applied a mixed research design, *Explanatory Sequential Design*, to explore the effect of DST on the development of pedagogical content knowledge of prospective math teachers on algebra. In explanatory sequential design, the general framework of the study is designated with the help of quantitative data. Qualitative data are utilized to support and make meaningful interpretations of quantitative data (Creswell, 2011; McMillan & Schumacher, 2010). A quasi-experimental single-group pretest-posttest design was employed in the quantitative part of the study (McMillan & Schumacher, 2010). The basis of applying a single-group pretest-posttest design is the existence of just one section of prospective math teachers enrolled each year at a Turkish university's undergraduate school of education. In the qualitative part of this study, the case study method was implemented to identify the views of prospective teachers on the DST process since the case study is likely to provide researchers with the opportunity to analyze a phenomenon, incident, object, program, system, process, etc. (McMillan & Schumacher, 2010) deeply.

*Participants*

The research sample consists of 52 third-year prospective math teachers who were enrolled as students at the undergraduate school of education of a Turkish university and took the Special Teaching Methods II course. The sample was selected through convenience sampling, a non-probability sampling method. In this sampling technique, researchers work with more convenient persons regarding transportation and cost (McMillan & Schumacher, 2010). Prospective teachers participating in the research had, by and large, an average level of achievement in Turkey's national university matriculation test. In the research, 44 participants were females, 84.6% of participants, and 8 participants were males, 15.4% of participants. Moreover, the real names of prospective teachers were not disclosed, given the ethical considerations of the research. In this direction, the names of prospective teachers were encoded from $PT_1$ to $PT_{52}$.

Successful completion of a four-year undergraduate program is a precondition to be eligible to be a secondary school math teacher in Turkey. During this undergraduate education, prospective teachers take courses on developing content knowledge, pedagogical knowledge, math teaching knowledge, and internship-type practical courses. Prospective teachers participating in this research already took courses on content knowledge and pedagogical knowledge. Although prospective teachers completed several math courses at the undergraduate level, they took no course on secondary school math yet. Hence, as part of DST activities performed under this research, prospective teachers will also deal with algebra concepts peculiar to secondary school math.

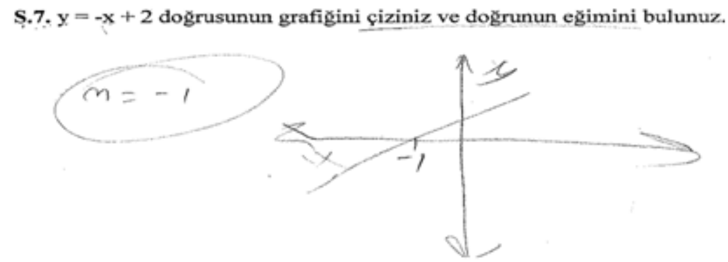
*Data Collection*

*Algebra Pedagogical Content Knowledge Test (APCKT)*

Algebra Pedagogical Content Knowledge Test is a paper-pencil test comprised of 10 scenario-type open-ended questions. An illustration of APCKT items is indicated in Table 1 below. Items were developed to measure knowledge of teaching strategies of prospective math teachers on KCS and KCT. APCKT was applied to prospective teachers both before and after DST activities as two independent applications in the classroom setting. The application of knowledge test took an average of 40-120 minutes. Researchers first reviewed the relevant literature before developing the knowledge test (Black, 2007; Bütün, 2012; Güler, 2014; Mccoy, 2014; Şahin, 2016) and created a question pool comprised of a total of 20 questions. Next, questions in the pool were examined by two content specialists, and of the questions measuring similar skills, only one question was maintained in the research. To designate the timespan necessary for completing the test, to directly observe application conditions of the test, and to see whether test items were sufficiently comprehensible for prospective teachers, APCKT composed of 10 scenarios was applied to 62 persons who were prospective math teachers but not participants of the research. It was agreed, upon the receipt of specialist views and the conduct of a pilot study, that APCKT would be utilized in the current research.

Table 1. Sample items of APCKT

| **Scenarios** | **Sub-areas of Learning** | **Scenarios** |
|---|---|---|
| Scenario 1 | Equations | Below is the hand-written answer by an eight-grade student as the answer to a question on drawing the graph of a line and finding its slope. Please check the student's answer and follow the instructions below. |

| | | |
|---|---|---|
| | | Student's answer:<br>S.7. Please draw the graph of line, y= -x + 2, and find its slope.<br><br> |
| Scenario 4 | Algebraic Expressions | A prospective teacher lectures on algebraic expressions in the context of compulsory internship program. On the board, prospective teacher noted down the following question: *"5 (3a+2)=?"*. A student came to the floor to solve the question on board. Student first made an explanation stating that *"Dear Teacher, if I sum 3a with 2, I will obtain 5a"*. |
| Scenario 5 | Identities | The below dialog took place between teacher Mr. Serdar and his student:<br>**Teacher:** $(2x + 3y)^2$ =? What is the identity for this expression?<br>**Student:** Dear Teacher, it is $2x^2 + 12xy + 3y^2$<br>**Teacher:** Do you not detect certain mistakes in the operation?<br>**Student:** Dear Teacher, I see no mistake, square of the first term is $2x^2$, isn't it? |

To measure KCS levels of prospective math teachers, the following questions were posed in APCKT: *"Please examine the situation in this scenario. Do you think that the student's answer is correct in this situation? If the student's answer is correct, please explain why it is so."* and *"If you think that the student's answer is incorrect, please explain why it is so."*. In a similar vein, to measure KCT levels of prospective math teachers, the following questions were included in the research: *"If you experienced this situation, how would you act in response to the student? What would you do in order to correct this* mistake*?"* In the allocation of algebra topics to questions of APCKT, Mathematics Course Curriculum (MoNE, 2018) was taken as the basis. In APCKT, scenarios were related to the following sub-areas of learning: two scenarios pertained to algebraic expressions, one scenario pertained to identities, one scenario pertained to inequalities, and six scenarios pertained to equations.

*Structured Interview Form*

A structured interview form developed by researchers was utilized to find out the views of prospective math teachers on DST activities. The interview form contains a total of five open-ended questions. The aim of using these questions is to ascertain the positive and negative effects of applying DST to the education of math teachers based on the experiences of prospective teachers. In the wake of DST activities, structured interviews were conducted in a classroom through a paper form to prevent prospective teachers from influencing each other. The listed questions below were raised in the structured interview form:

- What do you think of using the DST process in the education of math teachers?
- What type of contributions does the DST process offer to developing an occupational knowledge base and skills peculiar to the teaching profession?
- What are the positive impacts of the DST process on the comprehension of misconceptions/learning difficulties of secondary school students?
- What are the positive contributions of the DST process based on providing teaching clarifications to correct mistakes/eliminating learning challenges for secondary school students?

- What are the challenges you faced in the DST process, and what are the negative aspects of DST?

*Data analysis*

Rubric, a key tool for scoring performance levels and frequently employed in literature (Kwong et al., 2007; Şahin, 2016), was applied to analyze written responses from prospective math teachers to scenarios. In this rubric, there are five categories: no answer, wrong, partially correct B, partially correct A, and correct. Before analyzing responses given to APCKT by prospective teachers, researchers of this study created a data analysis framework for each sub-domain of PCK, which was addressed in this research. These data analysis frameworks are summarized in Table 2 and Table 3.

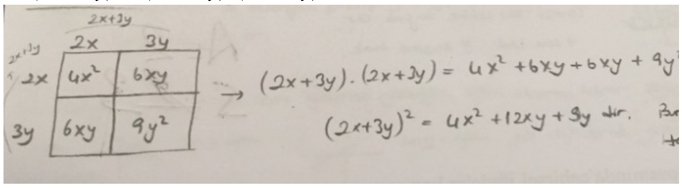
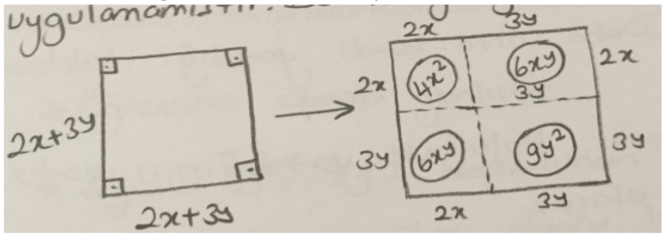
Table 2. Analysis framework for KCS (Question 1)

| Code | Explanation | Sample Response |
|---|---|---|
| Correct (3 points) | Describing/defining/explaning correctly the mistake made by the student through accurate use of math terminology. | *Student's answer is incorrect because we obtain the first equation when we expand the second equation with (-2) . Therefore, solution set is not all real numbers. The solution set of this equation is all points on equation, 2x-4y=8* (PT4-KCSpretest) |
| Partially Correct A (2 points) | Small mistakes in describing/defining/explaning the mistake made by the student, the case of a response which is closer to the correct one. | *Student's answer is incorrect because he/she eliminated unknowns in the equation and reached the result, 0=0. Based on this result, he/she assumed the equation was valid for all real numbers.* (PT32-KCSpretest) |
| Partially Correct B (1 point) | Using mathematically insufficient expressions in defining the mistake made by the student, the case of a response which is closer to the wrong one. | *Student's answer was incorrect because he/she stated that the solution was real numbers.* (PT24-KCSpretest) |
| Wrong Answer (0 point) | Using completely false or irrelevant mathematical and teaching expressions. Responding that there is no mistake made by the student. | *Student's answer was correct, there was no error. He/she solved equations jointly and found the correct answer.* (PT26-KCSpretest) |
| No Answer (0 point) | No response. | --------------------------------------- |

While describing the student's mistake in the la prospective math teacher, PT4, provided the correct response by stating that it was wrong to say the solution was all real numbers and the equation was valid for each point on the line. The response by the prospective math teacher, PT32, was deemed to be under the category 'partially correct A' because PT32 said it was incorrect that the student stated the solution set was real numbers and clarified why the student's answer was incorrect. The reason for the response by PT32 to be partially correct pertains to the failure of PT32 to state that this equation was valid for each point on the line. Prospective math teacher PT24 explained the student's mistake. However, the response by PT24 was deemed to be under the category 'partially correct B' because PT24 failed to talk about the reason for the mistake and included no comment about the correct answer for the equation. The prospective math teacher, PT26, provided an incorrect response for this scenario by claiming that the student made no mistake, although the student's answer was incorrect.

Table 3. Analysis framework for KCT (Question 5)

| Code | Explanation | Sample Response |
|---|---|---|
| Correct | Raising proper questions which is | *First, I would ask the student who finds* |

<table>
<tr><td>(3 points)</td><td>likely to ensure that the student comprehends his/her mistake and designing correctly the teaching process to ensure that the student is likely to avoid making mistake in the future.</td><td>$(2x+3y)^2=2x2+12xy+3y^2$ to assign values to x and y so that he/she sees both sides of the identity are equal to each other. For instance, if the student sees that $(2.1+3.1)^2=2.1^2+12.1.1+3.1^2$ □$25\neq17$ for $x=1$, $y=1$, he/she will comprehend his/her error. Afterwards, I model the identity with algebra tiles.<br>As $(2x+3y)^2=(2x+3y).(2x+3y)$:<br><br><br>Lastly, I inform the student that he/she should pay attention to coefficients when such expressions are squared. (PT11-KCTposttest)</td></tr>
<tr><td>Partially Correct A (2 points)</td><td>Raising insufficiently proper questions which is unlikely to guarantee that the student comprehends his/her mistake but designing correctly the teaching process to ensure that the student is likely to avoid making mistake in the future.</td><td>To avoid having this mistake in the future,<br><br><br>I make sure that the student finds the correct answer by modeling the area of above square whose side corresponds to (2x+3y). Student divides the square into 4 parts above and finds the area of each part and sums these areas.<br>Student finds $4x^2+6xy+6xy+9y^2=4x^2+12xy+9y^2$. (PT52-KCTpretest)</td></tr>
<tr><td>Partially Correct B (1 point)</td><td>Only raising questions which will make the student notice his/her mistake. Not raising questions which will make the student comprehend his/her mistake and designing insufficiently the teaching process that is likely to guarantee that the student avoids making mistake in the future.</td><td>I would display the correct answer by designing a model. I would ask the student to find the area of a square whose sides are equal to 2x+3y. (PT10-KCTpretest)</td></tr>
<tr><td>Wrong Answer (0 point)</td><td>Making absolutely false, irrelevant remarks or providing a comment which states directly the rule. Claiming that there is no mistake made by the student.</td><td>I would advise the student that he/she should perform the same operations for coefficients as he/she did for x and y. (PT36-KCTpretest)</td></tr>
<tr><td>No Answer (0 point)</td><td>No response.</td><td></td></tr>
</table>

Because prospective math teacher, PT11, posed questions that would make the student comprehend his/her mistake and modelled the identity correctly, his response was assessed as ‘completely correct’. The prospective math teacher, PT52, provided correct teaching clarifications, which guaranteed that students would likely avoid making mistakes in the future. However, the response by PT52 was placed under the category ‘partially correct A’ because PT52 failed to pose proper questions which would make the student comprehend his/her mistake. The response by the prospective math teacher, PT10, was put under the category ‘partially correct B’ because PT10 failed to raise questions that would make the student comprehend his/her mistake and designed insufficiently the teaching process that guaranteed that the student would likely avoid making mistake in the future. A prospective math teacher, PT36, asserted that he/she would remind the student about the rule. However, PT36 did not even mention which rule he/she would remind the student about, and so the response by PT36 was expressed under the category 'false.'

In quantitative research, a dataset should be evaluated by two different scorers or by the same scorers on different dates to test its reliability. Afterward, the correlation between these two scores is calculated (Cleophas & Zwinderman, 2015). Researchers analyzed the dataset twice on different dates. The intraclass correlation between these two scores was calculated as 0.994 ($p<0.05$) for the current research. Thus, it is observed that the reliability between scorers is quite high in the current research.

Kurtosis, skewness, Q-Q plot, histogram, and results of the Kolmogorov-Smirnov test ($n=52>50$) were all analyzed to identify whether the dataset obtained from APCKT was distributed normally (Büyüköztürk, 2018). Kurtosis and skewness coefficients need to be ±2, whereas mean, mode, and median values are supposed to be close to each other for normal distribution of datasets (Tabachnick & Fidell, 2013). It can be asserted that the dataset obtained for the current research is normally distributed because kurtosis and skewness coefficients, mean, mode, and median values are close to each other. However, Kolmogorov-Smirnov test was utilized before deciding which test to employ in the analysis of the research dataset. According to results of Kolmogorov-Smirnov test, it was found that pretest scores for KCS ($p_{pretestKCS} > 0.05$) and posttest scores for KCT ($p_{posttestKCT} > 0.05$) were normally distributed whereas posttest scores for KCS ($p_{posttestKCS} < 0.05$) and pretest scores for KCT ($p_{posttestKCT} < 0.05$) were not normally distributed (Table 4). Because it is revealed that pretest and posttest scores were not normally distributed upon the comparison of KCS and KCT scores, a non-parametric test, Wilcoxon signed-rank test was utilized for the comparison of KCS and KCT scores.

Table 4. Assumptions of normality

| | Kolmogorov-Smirnov Test | | | Mean | Mod | Median | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| | Statistics | sd | p | | | | | |
| KCS_PreTest | .143 | 52 | .010 | 9.65 | 10.00 | 10.00 | .087 | -.699 |
| KCS_PostTest | .149 | 52 | .006 | 15.52 | 16.00 | 16.00 | -.392 | -.304 |
| KCT_ PreTest | .171 | 52 | .001 | 5.44 | 5.00 | 5.00 | 1.036 | .901 |
| KCT_ PostTest | .099 | 52 | .200* | 16.81 | 17.00 | 17.00 | -.273 | -.204 |

Content analysis methodology was employed in the analysis of qualitative data of the current research. Content analysis was applied to the analysis of qualitative data with respect to views of prospective math teachers on DST. In content analysis, the research was performed in the context of the categories to explore the relationship between data and to advance conceptualizations (Yıldırım & Şimşek, 2018). In this research, researchers created codes and categories after receiving views of prospective math teachers on DST through written forms.

*Digital Storytelling Process*

Research was performed in the context of Special Teaching Methods II course. Digital stories were delivered in the conventional classroom setting of the course. Prospective teachers made use of their smart phones or laptop computers for developing stories. DST process was launched in the wake of the application of APCKT as pretest. In the first week, conceptual knowledge on DST was provided and sample digital stories were presented to prospective math teachers. In the second week, Web 2.0 tools such as Powtoon and Wevideo through which prospective teachers could develop their digital stories were introduced. Prospective math teachers were given the freedom to choose any digital platform to develop their stories. Prospective teachers were informed that they would be free to use any software as well as Web 2.0 tools introduced during the course. In the third week, prospective math teachers were asked to find a mistake frequently experienced in algebra learning. Prospective math teachers reviewed the literature for identifying the mistake to be examined in DST. Following the literature review, prospective teachers studied mistakes together with researchers in the third week. In the fourth week, prospective math teachers were asked to write a scenario covering a mistake of their own choice. In the fifth week, prospective math teachers designated such media as sound, images, video, music to be used in their digital stories and created storyboards. In the sixth week, prospective math teachers created their own digital stories by merging their media in software that they chose. In the seventh week, digital stories about each sub-area of learning such as algebraic expressions, equations, identities, inequalities were watched in the classroom. Questions requiring prospective math teachers to describe mistakes, to question the basis of mistakes, to ponder on the efficacy of teaching clarifications made for eliminating future mistakes and proposing an alternative solution technique were addressed and discussed. In the eighth week, APCKT was applied to prospective math teachers as posttest. Additionally, structured interviews were implemented to obtain views of prospective math teachers on DST.

## Findings

APCKT was applied to prospective teachers as pretest and posttest to ascertain the effect of DST on the development of pedagogical content knowledge on algebra. Moreover, structured interviews were utilized for addressing views of prospective teachers on DST. The findings obtained through APCKT and interview forms were presented through tables, graphs and direct quotations with regard to issues studied under the research.

*Findings on the development of pedagogical content knowledge*

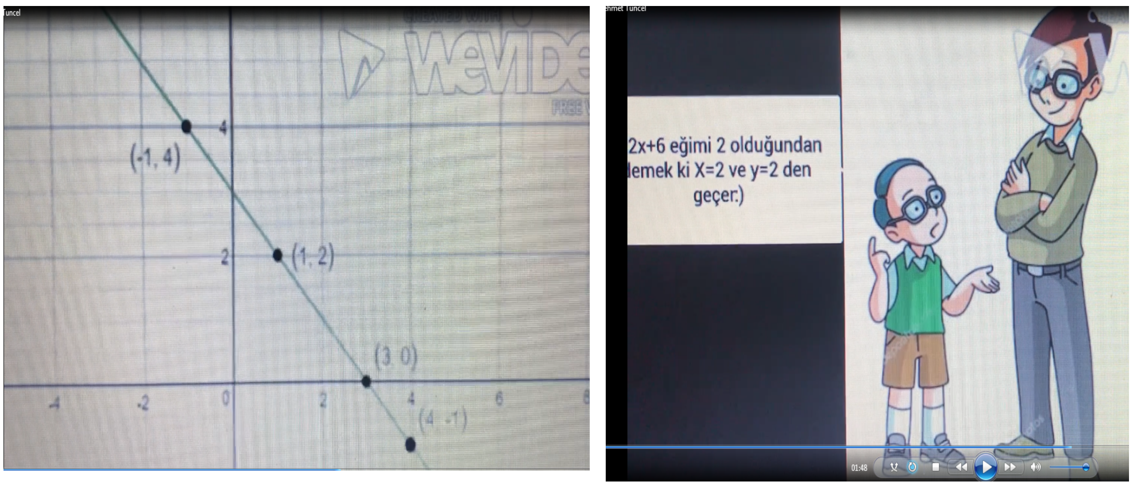
To discern whether there was a statistically significant difference between pretest and posttest scores of KCS and KCT of prospective teachers, Wilcoxon Signed-Rank Test was employed.

Table 5. Results of Wilcoxon Signed-Rank Test regarding KCS Pretest and Posttest Scores

| | | N | Mean Rank | Sum of Ranks | z | p |
|---|---|---|---|---|---|---|
| KCS Posttest-Pretest | Negative Ranks | 3[a] | 6.33 | 19.00 | -6,046[g] | ,000 |
| | Positive Ranks | 48[b] | 27.23 | 1307.00 | | |
| | Ties | 1[c] | | | | |
| KCT Posttest-Pretest | Negative Ranks | 0[d] | .00 | .00 | -6,283[g] | ,000 |
| | Positive Ranks | 52[e] | 26.50 | 1378.00 | | |

It is displayed in Table 5 shows a statistically significant difference between pre-test and post-test scores of KCS of prospective math teachers (z=-6.046, p<0.05). It is observed that when the mean of ranks and sums are considered, this difference is in favor of positive-signed ranks based on post-test scores. The mean of the pre-test scores of prospective math teachers for KCS was 9.65, whereas the mean of their post-test scores for KCS was 15.52. Given all these findings, it can be deduced that DST positively affects the development of KCS of prospective math teachers.

Prospective math teacher, PT7, misdescribed the student mistake through a response for the second scenario in pre-test phase of the current research by declaring that *"Solution is correct, however, it seemed like a coincidence. If there were no +2, student would fail to solve it correctly.*" PT7 correctly described the student mistake through a response for the second scenario in post-test phase of the current research by stating that *"Student assumed the slope value to be the x axis and drew a line crossing any point on y axis starting from x= -1. Student attempted to draw the line with the help of slope value*." PT7 prepared a digital story (Figure 1) about drawing linear equation during DST activities. In this sense, PT7 asked students to draw the graph of equation $y = 3x + 9$ in digital story. Student Ali drew the line graph in the exact opposite direction of his classmates' graphs. While drawing the graph, Ali assumed the slope to be the points where the line crossed *x* and *y* axes. Thus, DST contributed positively to the KCS of PT7.




Ali's wrong answer | Ali and his teacher are discussing

*Figure 1.* Sections from digital story of PT7

Response by prospective math teacher, PT23, which stated that "A number cannot be summed with an unknown" was assessed under the category 'partially correct B' in the fourth scenario in pretest phase of the current research because PT23 failed to say that the student summed an algebraic expression and constant number by assuming them to be as the same type. PT23 gave a 'correct' response by suggesting that *"Student summed a variable and a constant number as if they were of the same type by generalizing the summation of natural numbers to the summation of algebraic expressions."* for the fourth scenario in posttest phase of the current research. PT23 dealt with expressing a verbal problem in algebraic terms in a digital story. In this digital story, student İpek told that she would express the verbal question *"When a number is reduced by 4 and multiplied by 3, how do you express it?"* as $3x - 4$ in algebra terms. The digital story prepared by PT23 (Figure 2) handled the modeling of algebraic expressions. PT23 modeled different types of algebraic expressions in different models. It can be alleged that, based on responses given by prospective math teachers to APCKT and findings obtained from digital stories, DST has a positive effect on the development of KCS of prospective math teachers on algebra.

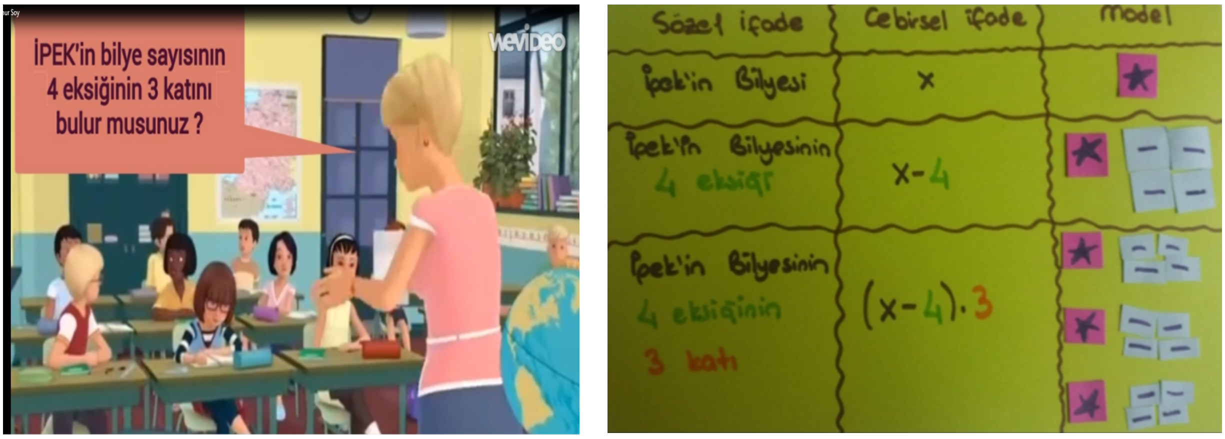
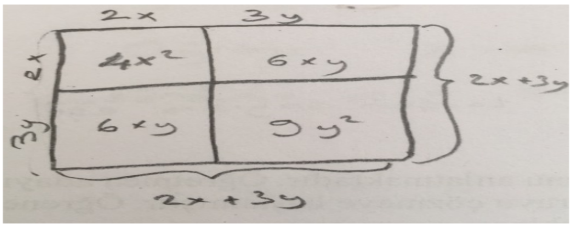



*Figure 2.* Sections from digital story of PT23

Table 5 indicates that there is a statistically significant difference between pretest and posttest scores of KCT of prospective math teachers ($z=-6.283$, $p<0.05$). It is observed that, when the mean of ranks and sums of difference scores are taken into consideration, difference is in favor of positive-signed ranks based on posttest scores. Additionally, mean of pretest scores of KCT of prospective math teachers was 5.44 whereas the mean of their posttest scores of KCT was 16.81. Because of all these findings, it can be deduced that DST is a method which has a positive effect on the development of KCT of prospective math teachers.

Response by prospective math teacher, PT51, which stated that *"I would use modelling for clarification. Also, to set as an example, I would solve questions on the squaring of expressions, coefficients of which are not equal to 1."* was assessed under the category 'partially correct B' in the fifth scenario in pretest phase of the current research because prospective math teacher did not demonstrate how he/she would solve sample questions and design the model. On the other hand, PT51 provided a 'correct' response for the fifth scenario in posttest phase of the current research (Figure 3).

*First, I would make sure that the student sees whether identity equals the extension created by the student by asking him to assign values to unknowns. Given that x=1 and y=2, $(22.1+3.2)^2=2.1^2+12.1+3.2^2$ □ $64\neq38$. As the results in both sides are unequal, the student will notice his/her error. Later, we model the identity through algebra tiles.*




*Area of this square equals the sum of areas of parts corresponding to $(2x+3y)^2$.*

*We avoid making error in the future by ensuring that the student sees the extension of identity should be as $(2x+3y)^2= 4x^2+12xy+9y^2$ via the figure of a square.*

*Figure 3.* Response by PT51, to the fifth scenario in posttest

PT51 mentioned about a mistake of a student on identities such as $(x+y)^2 = x^2 + xy^2 + y^2$ in his/her digital story. PT51 also utilized the modelling of identities in his/her digital story (figure 4) for ensuring that the student overcomes the mistake.


*Figure 4.* Sections from digital story of PT51

The response by prospective math teacher, PT19, which, to guarantee that the student would likely avoid making mistake in the future, stated that *"I would let students solve the question once again after reminding them about the priority sequence of operations. I ask the student to substitute the result, x=5, for the unknown in the equation. When the student sees the following discrepancy, 16=13, he/she is likely to notice that there is an inconsistency in the operation. If the student fails to notice his/her mistake, I try to make him find the correct answer by offering more questions and directions."* was assessed under the category 'partially correct B' in the eighth scenario because PT19 accurately made sure only that the student noticed his/her mistake. However, PT19 offered no teaching clarification for guaranteeing that the student would likely avoid making mistake in the future. On the other hand, PT19 gave the 'correct' response in the posttest phase of the current research by first asking the student to substitute a value for the unknown and then by applying the scales model (Figure 5).

*First, I would ask the student to substitute x=5 for the unknown in the equation in order to ensure that the student noticed his/her mistake and the student would understand that he/she made an mistake when he/she saw the following discrepancy, 16≠13. Later on, I would offer a visual representation of the given equation via the scales model.*

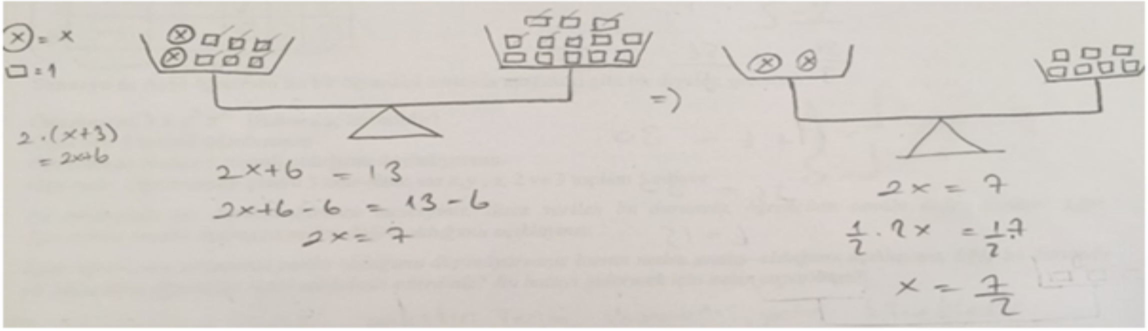



*Figure 5.* Response by PT19, for the eighth scenario in the posttest

In his/her digital story (Figure 6), PT19 dealt with a mistake akin to the one in the eighth scenario of APCKT. In this scenario, while solving the equation, $2x = 6$, one of the students made the following mistake: $(2 - 2)x = 6 - 2 \ \rightarrow x = 4$. PT19 made use of the scales model to correct the student's mistake. It can be proposed that, based on responses given by prospective math teachers in APCKT and findings obtained from digital stories, DST has a positive effect on the development of KCS of prospective math teachers with respect to algebra.

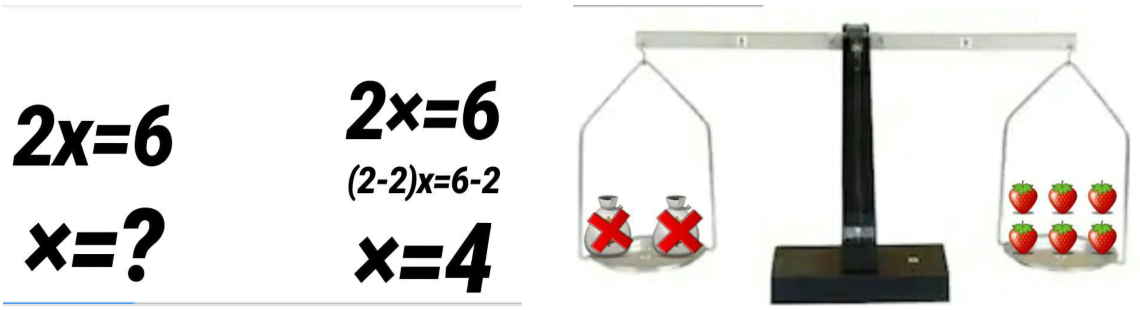



*Figure 6.* Sections from digital story of PT19

*Findings on views of prospective math teachers on DST*

Table 6 summarized categories and codes obtained upon the analysis of comments made by prospective math teachers based on the structured interview form. Comments made by prospective teachers were placed under two categories, either positive or negative.

Table 6. Comments about digital storytelling

| **Categories** | **Codes (f)** |
|---|---|

| | |
|---|---|
| Positive | Understanding students (43)<br>Teaching Strategies<br>    Correcting Mistakes (44)<br>    Effective Teaching (19)<br>    Different Method & Technique (5)<br>    Active Participation (6)<br>    Permanency (16)<br>Sensational<br>    Self-confidence (3)<br>    Attractive (26)<br>    Enjoyable (12)<br>    Empathy (4)<br>    Attitude (1)<br>Knowledge of Technology (13)<br>Cognitive Skills<br>    Creative Thinking (8)<br>    Problem Solving (2) |
| Negative | Uneconomicalness<br>    Time-consuming (21)<br>    Requiring a lot of labor (11)<br>    Costly (2)<br>Technological Difficulties<br>    Media Creation (22)<br>    Technological Preparedness (14)<br>    Practice-based Problems (19)<br>Challenges faced in Scenario Production (17) |

*Positive Aspects*

Prospective math teachers providing positive feedback argued that DST positively supported the development of understanding the students, knowledge of teaching strategies, technology, cognitive skills, and sensational characteristics of teachers and students. Quite a few prospective teachers underscored that they started to better comprehend students' thoughts, misconceptions, mistakes, and learning styles by virtue of DST. Comments made in this direction by prospective math teachers are exhibited below:

> *"DST contributed to my comprehension of misconceptions and the basis of misconceptions." (PT10)*
>
> *"We are able to go down to the student's level. We are able to think in the same vein as students…" (PT12)*
>
> *"I was able to have the same thoughts as the student. I was able to learn what type of misconceptions students could have and how they would reach solutions." (PT20)*
>
> *"DST helps to know and understand the student and, by going to the student's level, to comprehend in what way the student would think." (PT23)*

Almost all prospective math teachers underlined that DST fostered the development of their knowledge of teaching strategies. Prospective math teachers noted that, through storytelling, they learned how to correct misconceptions, teach concepts most effectively, enable the active involvement of students in the lesson, and ensure the permanency of learning. Additionally, certain prospective math teachers suggested that their teaching techniques and technical knowledge were enriched through storytelling activities. Comments made in this direction by prospective math teachers are demonstrated below:

*"Digital stories can enable students to participate in the lesson more actively." (PT8)*

*"DST made a positive contribution by providing a framework on how to correct prospective misconceptions likely to emerge in the lesson." (PT9)*

*"It is possible to correct misconceptions enjoyably and permanently through DST." (PT35)*

*"It lets teacher determine which method is more beneficial for teaching a topic." (PT42)*

*"It enabled me to think about methods to be applied by us to correct misconceptions." (PT49)*

Prospective math teachers alleged that the DST process was attractive and enjoyable. Furthermore, they note that DST could buttress the development of empathy skills, attitude toward math, and self-confidence. Comments made in this direction by prospective math teachers are indicated below:

*"By virtue of learning a topic through visual presentations, topic will appear more interesting to students, and the attitude of students toward math will be influenced positively." (PT8)*

*"In order to make math more interesting and enjoyable, DST can be utilized." (PT15)*

*"Feeling myself as if a real teacher, I realized how I could assure permanency in learning." (PT28)*

*"We emphasized with the student's thinking and perspective." (PT38)*

*"The use of such technologies in math teaching will make the self-confidence of teachers go up." (PT51)*

Additionally, prospective math teachers referred to the development of technology knowledge and cognitive skills as part of the positive implications of DST. Comments made in this direction by prospective math teachers are highlighted below:

*"We gained a more advanced knowledge of computer use." (PT13)*

*"DST urges prospective math teachers who are not savvy about the use of technology to interact more with technology." (PT16)*

*"I think that DST encourages us to be more engaged with technology and enhances our creativity." (PT19)*

*"DST process endows a teacher with skills in problem-solving, using technology, knowing students, eliminating* mistake*s." (PT39)*

*Negative Aspects*

Prospective math teachers providing negative feedback stressed that DST was uneconomical and posed technological difficulties, and they also talked about the challenges faced in scenario production. Prospective math teachers reporting that DST was an uneconomical process argued that DST was time-consuming, costly, and requiring much labor. Comments made in this direction by prospective math teachers are noted below:

*"DST process required a lot of effort, and took me a long time." (PT9)*

*"There are certain challenges as DST is a process taking long time, demanding*

*manual labor and requiring sufficient economic means." (PT13)*

*"Being a time-consuming activity is among negative aspects of DST." (PT40)*

Prospective math teachers highlighting the technological difficulties of DST referred to challenges faced in creating media such as sound, music, and images, the trouble in using software, and insufficient level of technological preparedness. Comments made in this direction by prospective math teachers are stated below:

*"I had trouble in finding sound, images and video fitting my digital story." (PT4)*

*"I devoted a whole day in order to find a cartoon fitting my digital story. I spent exactly 2 days for cutting and copying certain scenes from a 30-minute cartoon show." (PT20)*

*"I had difficulty in generating voice-over for each image." (PT21)*

*"We had problems such as recording sound and video because the software we were supposed to use was not free and unlimited edition." (PT33)*

*"I had trouble in DST on grounds of having an insufficient level of technological knowledge." (PT43)*

*"I had issues in recording a video in the software I used most frequently. I had to prepare video twice from scratch." (PT46)*

Certain prospective math teachers said that the most challenging DST issue was writing a story, scenario, or tale fitting the mistake they had chosen. Prospective math teachers had trouble designating heroes, venues, mistakes, and dialogs they would use in digital stories. Comments made in this direction by prospective teachers are noted below:

*"I had difficulty in finding what type of materials would help me correct mistake and what type of a hero I would employ in my digital story." (PT35)*

*"I was faced with difficulty in designing the story in DST process. Mathematical side of the story was not challenging, however, transforming it into a story was a demanding activity." (PT38)*

*"I had hardship in choosing a misconception and creating a story out of this misconception." (PT48)*

*"Thinking about such issues as time, venue, characters of the story, equipment, idea, setup and how I can express it better challenged me." (PT50)*

## Discussion & Conclusion

### *Development of knowledge of pedagogical content of prospective teachers*

The research was performed to analyze the effect of DST on the development of prospective secondary school teachers' algebra pedagogical content knowledge with the help of Explanatory Sequential Design. In line with the objectives of the research, APCKT and structured interview forms were applied to 52 prospective teachers. The research used KCS and KCT sub-domains of PCK (Ball et al., 2008). At the end of the research, there was a statistically significant development in PCK sub-domains, KCS & KCT, of prospective math teachers about algebra. It can be asserted that (i) having the opportunity to explore mistakes in the literature, (ii) attempting to define mistakes in the DST process, (iii) providing teaching clarifications in digital format for ensuring the most effective correction of mistakes had positive effects on PCK development of prospective math teachers for correcting mistakes of secondary school students. Besides, prospective math teachers had, in a classroom setting, the chance to watch and discuss digital stories for each sub-area of learning, i.e., algebraic expressions, identities, equations, and inequalities, and compare them with different digital stories that they prepared. Thus, it was deduced in this research that DST was a teaching technique to be applied in the education of teachers to promote the development of PCK of math teachers and prospective math teachers concerning algebra mistakes.

In the relevant literature, there appeared to be no research applying DST to developing PCK on mistakes of math teachers and prospective math teachers. There are still a few studies applying DST to teaching education in the relevant literature (Røkenes & Krumsvik, 2014). Case-based studies (Barnett, 1991; Lin, 2005), structured interviews (Jenkins, 2010), coaching (Stewart, 2013), microteaching (Hadfield et al., 1998), lesson study (Baki, 2012), microteaching lesson study (Fernandez, 2010), teaching experiment (Chamberlin & Candelaria, 2018), vignette (Hauk et al., 2013) and alternative occupational knowledge development programs designed by researchers (Burton, et al., 2008; Lannin et al., 2013) were among methods frequently applied to assure the development of PCK of math teachers and prospective math teachers. Moreover, it was suggested that DST was essentially intended for the learning process of students and DST had positive effects such as raising the achievement and motivation level of students (Hung et al., 2012; Sadik, 2008; Yang & Wu, 2012), raising the interest of students in the lesson (Sadik, 2008; Yang & Wu, 2012), securing a meaningful learning experience for students (Yang & Wu, 2012), enabling the correction of misconceptions of students (Karaoglan Yilmaz et al., 2018) and enhancing problem-solving skills of students (Hung et al., 2012).

In the literature, studies on the DST experience of teachers and prospective teachers focus by and large on technological pedagogical content knowledge (TPACK) (Sancar-Tokmak et al., 2014) and self-competency (Heo, 2009), self-confidence (Sancar-Tokmak & Yanpar-Yelken, 2015) and teacher dispositions (Heo, 2009; Vannatta & Fordham, 2004). Besides, certain studies alleged that DST enabled teachers and prospective teachers to teach concepts more effectively and supported the development of pedagogical content knowledge of teachers and prospective teachers (Istenic Starčič et al., 2016; Sadik, 2008). Istenic Starčič et al. (2016) asserted that DST developed pedagogical content knowledge and math knowledge of prospective teachers. Sancar-Tokmak et al. (2014) argued that technological knowledge, pedagogical knowledge and content knowledge of prospective teachers were enhanced through DST. In the quasi-experimental study conducted by Heo (2009) to analyze the effect of DST on technological self-competency and dispositions of prospective teachers, it was observed that DST upheld the development of both aforementioned variables of prospective teachers. Vannatta & Fordham (2004) suggested that DST enhanced the openness to change of prospective teachers towards educational technology. Sancar-Tokmak and Yanpar-Yelken (2015) revealed a statistically significant development in TPACK self-confidence of prospective foreign language teachers due to DST.

*Views of prospective math teachers on DST*

Prospective math teachers claimed that DST supported the development of understanding students, knowledge of teaching strategies, technology, cognitive skills, and sensational characteristics of students. Quite a few studies in the literature addressed positive aspects of DST. In the studies on DST, developing knowledge of technology (Özpınar, 2017), learning how to teach concepts (Faruk Islim, et al., 2018; Giles & Kent, 2016; Sadik, 2008), offering the opportunity to enrich learning atmosphere (Özpınar, 2017; Sadik, 2008), enabling the active involvement of students in the lesson (Özpınar, 2017), developing cognitive skills such as problem solving (Giles & Kent, 2016) were among positive impacts of DST on occupational development of teachers and prospective teachers. Teachers participating in the research by Sadik (2008) declared that DST enriched the learning atmosphere, and further claimed that they could deliver more effectively concepts in the curriculum to students. In the study by Özpınar (2017), prospective math teachers suggested that they could enable students' active participation in the lesson through DST and enrich the learning atmosphere, and technological competency was improved. Giles & Kent (2016) argued that prospective teachers learned how to teach concepts, gained the knowledge of using new technological gadgets, and problem-solving and process-management skills prospective teachers were enhanced along with the DST process in the study performed with the participation of five teachers. Faruk Islim et al. (2018) reported that prospective math teachers would use DST in the future when they were employed as teachers, learned how to teach concepts through DST and acquired a new teaching technique. Discussion of the relevant literature and results of this research indicate that teachers and prospective teachers had positive views on DST in general. It can be hinted that the reason for teachers and prospective teachers to declare positive views on DST pertains to the fact that they are competent enough to utilize today's technologies actively and can create their own media (sound, music, images) freely (Robin, 2008).

Prospective math teachers asserted at the end of the research that DST was time-consuming, costly, and required a lot of effort. Prospective math teachers highlighting technological hardship peculiar to DST referred to the difficulty in creating media such as sound, music, images, software-based challenges, and insufficiency of technological preparedness. Certain prospective math teachers claimed that the most challenging aspect of DST was to write a story, scenario, or tale fitting the mistake. Similarly, certain negative aspects of DST were noted in the relevant literature. Albano and Iacono (2019) suggested that certain prospective teachers had difficulty designing verbal problems through DST. The study by Sadik (2008) indicated that it took teachers a long time to devise course plans for DST; teachers also talked about certain problems, such as the insufficiency of technical equipment (computers, tablets) and internet connection mistakes. Prospective teachers also reported disadvantages of DST the following: cost of technological equipment for DST, difficulty with the application of DST in crowded classrooms, long duration of time devoted to DST, trouble in managing the classroom during DST sessions (Yuksel-Arslan et al., 2016). The study by Özpınar (2017) stated that prospective teachers underlined that DST was time-consuming, it failed to provide effective teaching if it was not well-planned and well-prepared, and the writing process of a story was challenging. Moreover, Duveskog et al. (2012) and İnan (2015) stressed the negative aspects of DST such as being time-consuming and costly. Upon discussion of the relevant literature, negative aspects of DST can be summarized under three categories: costliness, problems based on technological equipment, and difficulty in writing scenarios.

## Recommendations & Limitations

The current research was performed to analyze the effect of DST on the development of pedagogical content knowledge on algebra of 52 prospective math teachers who were enrolled as students at the undergraduate school of education of a Turkish university. Prospective math teachers themselves prepared digital stories in the research, and this process took eight weeks. A single-group pretest-posttest design was employed in the current research because there was just one section of the class of prospective math teachers in each year of the undergraduate school of education. In the future, empirical studies, including a control group and treatment group, can be conducted. Besides, the current research was performed in a crowded classroom. This situation obliged researchers to spend a short timespan per prospective math teacher in the DST process. The fact that the software was not free and the software price was much higher than the one prospective math teacher could afford was another issue affecting this research negatively. Therefore, prospective math teachers were forced to use the one-week trial of the software, and prospective math teachers were in a hurried mood during the process since the software was a limited trial version. As certain prospective math teachers failed to create videos in a week, they had to record them again from scratch. To overcome such technical bottlenecks, such research must be performed with financial assistance to be obtained under the auspices of certain institutions.

A knowledge test composed of a total of ten scenarios was implemented in the current research as the scope of algebra learning was too broad. A more specific concept, such as an equation or identity, can be analyzed, and a test comprised of a smaller number of scenarios can be applied in the next research. Thus, it can be possible to make deeper analyses and inferences. The fact that observation was not used as an instrument for measuring the development of PCK of prospective math teachers through DST is another limitation of the current research. Intra-class observations can be utilized in future research to examine the occupational knowledge development of prospective math teachers along with DST. The current research displayed that DST had a positive effect on the sub-domains of PCK, KCS, and KCT. Hence, it will be helpful to apply data communication technologies to the education of math teachers. Additionally, research addressing the effect of DST on other sub-domains of PCK, such as subject matter knowledge and teaching program knowledge, can be undertaken in the future.

Disclosure statement

No potential conflict of interest was reported by the authors.

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