한국학교수학회논문집 제 19 권, 제 4 호
Journal of the Korean School Mathematics Society
Volume 19, Number 4, 459-478, December 2016

The Influence of Preservice Teachers' Experience and Beliefs Related to Technology Use in Mathematics Class on Their Technology-related Knowledge

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With the proven benefits of and increased interest in using technology in education, the role of teachers has become more important in integrating technology into mathematics classroom. Thus, it is important to improve preservice teachers' technological, pedagogical, and content knowledge (TPACK), which are influenced by their beliefs. This study examines how preservice secondary mathematics teachers' experience and beliefs related to technology use in the mathematics classrooms impact their TPACK. The results of this study show that preservice teachers who have more experience using technology and who hold student-centered beliefs towards technology use display higher levels of technology-related knowledge than preservice teachers who have little experience and who hold teacher-centered beliefs. Understanding the relationships between preservice teachers' TPACK and beliefs provides insights into how teacher education programs can support preservice teachers to develop TPACK and integrate technology into their future mathematics instruction.

Key Words: TPACK, preservice secondary mathematics teachers, teacher beliefs, dynamic geometry environment

I. Introduction

With the variety of technology available, mathematical learning and teaching techniques have become dynamic, diverse, and effective. Many researchers have

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demonstrated technology's positive effect on the mathematical learning process. Technology does not only help students acquire computation skills; it also facilitates the acquisition of mathematical ideas, conceptual understanding, and connections among various representations (e.g., Kaput, Hegedus, & Lesh, 2007; Roschelle et al., 2010).

The National Council of Teachers of Mathematics (NCTM, 2000) emphasized technology's capability to engage students in high-level thinking and in-depth mathematics learning as well as the role of a teacher in a technology-rich classroom: "The teacher plays several important roles in a technology-rich classroom, making decisions that affect students' learning in important ways. Initially, the teacher must decide if, when, and how technology will be used" (p. 26). Preservice and current mathematics teachers are encouraged to use technology in mathematics classrooms and are expected to be able to make judicious decisions when integrating technology.

Many teacher education and professional development programs provide technology-related courses to improve preservice or current teachers' knowledge about technology integration and teaching practices with technology (Niess, 2012; Mouza, Karchmer-Klein, Nandakumar, Ozden, & Hu, 2014). The preservice teachers and current teachers, however, did not use technology in student-centered approaches believed to be the best ways to facilitate students' learning (Ottenbreit-Leftwich, Glazewski, Newby, & Ertmer, 2010). According to Mouza et al. (2014), while "this generation of preservice teachers is more technologically savvy and actively engaged with digital media, knowledge and skills alone are not sufficient conditions for curricular use of technology in support of rigorous standards" (p. 206). Preservice teachers' beliefs are another significant determinant of effective technology integration. To improve effective technology use of preservice mathematics teachers, it is essential for teacher education programs to focus on preservice teachers' beliefs towards and knowledge of mathematics, pedagogy, and technology (Crompton, 2015).

Despite the importance of preservice teachers' beliefs and knowledge in developing their ability to incorporate technology into mathematics teaching, little research on both beliefs and knowledge regarding mathematics, pedagogy, and technology use has been conducted. The purpose of this study is to examine how preservice secondary mathematics teachers' experiences and beliefs regarding technology use in mathematics classrooms relate to their knowledge of how to integrate technology into mathematics teaching.

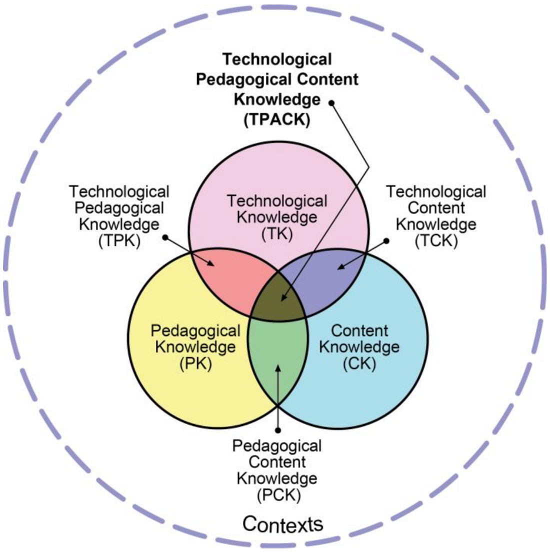
II. Literature Review

1. Preservice Teachers' Beliefs

Many researchers have been interested in and have investigated preservice or current teachers' beliefs and the influence of such beliefs on their teaching practices (e.g., Kim, Kim, Lee, Spector, & DeMeester, 2013; Pajares, 1992). Although some researchers have shown that teachers' practices are not always consistent with their beliefs (Raymond, 1997; Thompson, 1992), beliefs are still a strong foundation for teaching practices (Kim et al., 2013; Pajares, 1992). For instance, teachers' particular methods of teaching mathematics or of using their knowledge are affected by their beliefs towards what mathematics is and how to teach and learn it (Brown & Cooney, 1982). In particular, preservice teachers' idealistic, deep-seated, and traditional beliefs about teaching and learning (Richardson, 2003) strongly affect how they interpret what they learn and how they use or reflect their knowledge into their decision-making in their later teaching practices as teachers (Pajares, 1992). Kay and Knaack (2005) stated that preservice teachers' beliefs are also crucial factors that influence their technology integration. Preservice teachers' previous experiences in learning or student teaching in the field may obstruct their use of technology in teaching practices. If they have few or negative experiences and beliefs about technology, they may not use technology or use it in limited ways in their teaching (Crompton, 2015). For example, in Turner and Chauvot's (1995) study, preservice secondary mathematics teachers stated that they would not let their students use technology until they know how to calculate by hand because the preservice teachers believed successful technology use in mathematics requires that students have previous knowledge about the topic. Suhawrotto, Lee, and Chae (2009) also indicated that preservice secondary mathematics teachers' beliefs about technology affected their use of technology in student teaching. First, they found that preservice teachers with stronger beliefs about the multiple benefits of technology in learning and teaching tended to consider longer and more consistent use of technology in their lesson plans. Furthermore, preservice teachers who were more convinced that students could improve their mathematical understanding using technology had their students use technology in more diverse ways, such as group activities and individual projects.

2. Technological, Pedagogical, and Content Knowledge (TPACK)

In addition to beliefs, preservice teachers' knowledge about how to teach a subject matter using technology is an important factor that influences their effective technology integration (e.g., Choy, Wong, & Gao, 2009; Pamuk, 2012). To effectively integrate technology into instruction, preservice and current teachers should have intertwined and specialized knowledge, which is defined as Technological Pedagogical Content Knowledge (TPACK; originally TPCK) by Mishra and Koehler (2006). Based on Shulman's (1986) descriptions of Pedagogical Content Knowledge (PCK), the TPACK framework comprises three main components: Content, Pedagogical, and Technological Knowledge (CK, PK, and TK) and the intersections between and among them, represented as PCK, Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and TPACK (also called TPCK; see Figure II – 1 and Table II – 1).



[Figure II – 1] The TPACK framework and its knowledge components (http://tpack.org).

As effective technology integration approaches, many teacher education programs encourage preservice teachers to use technology for collaborative, inquiry-based, or problem-solving activities in their teaching (Culp, Honey, & Mandinach, 2005; Ottenbreit-Leftwich et al., 2010). Recent studies, however, provide evidence that the preservice teachers lack appropriate knowledge to effectively integrate technology into mathematics instruction (e.g., Choy et al., 2009; Pamuk, 2012; Özgün-Koca, Meagher, & Edwards, 2010). In Pamuk's (2012) study, preservice middle school and high school teachers had difficulties in developing interlaced knowledge, such as TPK and PCK, and it resulted in a lack of TPACK. Similarly, Özgün-Koca et al. (2010) indicated that preservice secondary mathematics teachers struggled to design exploratory tasks due to a shortage of PCK and TK.

<Table II - 1> Descriptions of the TPACK Framework Components

Components of TPACK	Description
Content Knowledge (CK)	Knowledge of the actual subject matter to be learned or taught, including central concepts, theories, and organizing or connecting ideas.
Pedagogical Knowledge (PK)	Knowledge of the processes and practices or methods of teaching and learning, including classroom management, development and implementation of lesson plans, and student assessment.
Technology Knowledge (TK)	Knowledge of the standard and advanced technologies, including the skills to install, remove, and operate particular technologies.
Pedagogical Content Knowledge (PCK)	Knowledge of pedagogy that is applicable and appropriate to teaching specific content.
Technological Content Knowledge (TCK)	Knowledge of the manner in which technology and content relate to, influence, and constrain each other.
Technological Pedagogical Knowledge (TPK)	Knowledge of the capability of various technologies including affordances and constraints that influence pedagogical designs and strategies in a teaching and learning setting.
Technological Pedagogical Content Knowledge (TPACK)	Knowledge of the interaction among content, pedagogical, and technological knowledge that requires an interweaving of specialized knowledge for teaching with technology.

3. Beliefs and Knowledge about Teaching with Technology

With a lot of research on beliefs and knowledge (e.g., Furinghetti & Pehkonen, 2002; Pajares, 1992; Thompson, 1992), many researchers agree beliefs and knowledge cannot be clearly distinguished because they are closely related to one another (Scheffler, 1965; Thompson, 1992). As Crompton (2015, p. 243) indicated that TPACK is not a body of knowledge that exists independently of beliefs, beliefs and TPACK are also linked inextricably. In Niess' (2015) developmental model of mathematics teachers' TPACK, there are four different aspects of knowledge with five developmental levels. In the developmental model, teachers' beliefs are deeply involved with knowledge aspects and teachers' TPACK levels such that teachers' certain beliefs are related to their certain levels of TPACK. In Smith, Kim, and McIntyre's (2016) study, preservice middle school teachers who had student-centered beliefs about mathematics, pedagogy, and technology had higher levels of CK, PCK, and TPCK, respectively, than preservice teachers who had teacher-centered beliefs. In addition, Mudzimiri (2010) indicated that preservice secondary mathematics teachers' beliefs about technology use progressed, as well as their improvement of TPK, TCK, and TPACK, through technology-intensive courses. Thus, these studies suggested that preservice teachers' beliefs are consistent with their levels of TPACK components.

III. Methodology

1. Participants and Context

The participants were four undergraduate preservice teachers enrolled in a mathematics teacher education program at a university in the southern region of the United States. They volunteered for this study and were enrolled in a secondary mathematics pedagogy course that was about learning and teaching geometry, probability, and sequences and series using technology. The main goal of the course was to develop preservice teachers' knowledge about using technology in mathematics classrooms and how technology influences students' mathematical thinking and understanding. Because the course instructor regularly provided activities using diverse technological tools to explore mathematical concepts, the participants were familiar with technological tools, such as Geometer's Sketchpad 5 (GSP), and with solving and explaining geometry problems. I collected data after the pedagogy course was over so that there was no implied connection between participating in the study and their course grades.

2. Data Collection

To identify participants' beliefs, I used Smith et al.'s (2016) semi-structured beliefs interview protocol consisting of 74 questions in four categories: the nature of mathematics, learning mathematics, teaching mathematics, and technology use in mathematics classes (see Table III - 1). To examine participants' TPACK components (CK, PCK, TCK, and TPCK), I used Hollebrands and Smith's (2010) task-based interview protocol containing four tasks regarding geometry topics (see Figure III - 1). In the task-based interview, the participants were asked to create activities using GSP to help students develop mathematical understanding or to remedy the students' misconceptions. During this interview, each participant could use a laptop with GSP, the pedagogy course textbook, a compass, a protractor, a ruler, blank paper, and pencils.

<Table III - 1> Sample Questions from Beliefs Interview Protocol (Smith et al., 2016)

Area	Questions
Nature of Mathematics	When you hear the term mathematics, what do you think of? Could you describe what you are thinking about the difference between mathematics and the other subjects?
Learning Mathematics	How do you think students learn mathematics? What do you think is the most important aspect of mathematics that students should learn? In other words, what part of mathematics do you want students to be really good at?
Teaching Mathematics	In order to be a good mathematics teacher, what do you think are the most important things for a teacher to do? What do you think the role of mathematics teacher should be? You can give more than one role
Learning and Teaching Mathematics with Technology	How do you think the use of technology affects students' mathematical thinking? When preparing lessons that incorporate technology, what do you take into account?

To investigate how participants use GSP to teach a specific mathematical topic, I conducted a performance interview in which they demonstrated how they would teach the exterior angle

TASK1

Suppose students in your middle or high school mathematics class are studying rectangles and squares. They open a dynamic geometry sketch that contains a rectangle and a square, each of which has been constructed. Students are asked to consider properties of rectangles and squares, based on their exploration of the sketch. One pair of students has measured the diagonals and they have noticed they are always congruent. They claim, "quadrilaterals have congruent diagonals."

a. Is this claim always true, sometimes true, or never true? Explain.
b. How would you characterize their current level of geometric understanding?
c. Create a sketch using a dynamic geometry environment that you would like students to use to explore diagonals of quadrilaterals. Be sure to include directions and/or questions you would provide to students as they use this sketch.

[Figure III – 1] Sample Task for Measuring Participants' TPACK. Adapted from "Assessing prospective secondary teachers' knowledge of geometry, technology, and pedagogy," by K.F. Hollebrands and R. C. Smith, 2010, Methods and purposes for assessing high school teachers' knowledge of geometry.

theorem (the sum of the measures of the exterior angles of a convex polygon is 360) using GSP. This interview was designed to measure participants' TPACK through their instructional design and decision-making based on their pedagogical reasoning and ability to teach geometry using GSP (Harris, Grandgenett, & Hofer, 2010). By adding the performance interview, this research improved the data collection process used in a previous Smith et al.'s (2016) study, in which only beliefs and task-based interviews were conducted. Through the performance interview, I could thoroughly investigate the participants' TPACK that was not covered in the task-based interview and its rubric and find evidence to support the task-based interview results. In addition, the performance interview allowed me to observe how participants actually plan and implement a lesson about a mathematics concept using GSP. In the pedagogy course, the participants did not learn the exterior angle theorem, and there were various possible strategies by which the theorem could be taught. Thus, the theorem was appropriate to use for assessing the participants' levels of TPACK components. Before the performance interview, the participants had time to prepare teaching materials (e.g., pre-constructed GSP files or worksheets) in advance or to make them during the interview. During the interview, each participant could use a laptop with GSP, blank paper, and pencils. Each of the three interviews took approximately one hour and was video- and audio-recorded.

3. Data Analysis

To assign codes for participants' beliefs, I used Smith et al.'s (2016) beliefs classification that consists of Ernest's (1989) classification of mathematics teachers' beliefs and Goos, Galbraith, Renshaw, and Geiger's (2003) perspectives of technology use (see Table Ⅲ - 2). I wrote each participant's narrative about his/her beliefs and gave it to each participant to perform a member check (Creswell, 2013). All participants agreed that I accurately described their beliefs.

<Table Ⅲ - 2> Classifications of Mathematics Teachers' Beliefs

Beliefs about	Classification of beliefs	Description
Nature of Mathematics (Ernest, 1989)	Instrumentalist	Mathematics is a set of facts and rules
	Platonist	Mathematics as a unified body of certain knowledge that does not change
	Problem Solving	Mathematics as a human creation that is continually changing
Learning (Ernest, 1989)	Passive Reception of Knowledge	Child exhibits compliant behavior and masters skills. Child passively receives knowledge from the teacher
	Active Construction of Knowledge	Child actively constructs understanding. Child autonomously explores self interests

Teacher's Role (Ernest, 1989a)	Instructor	Goal of instruction is for students to master skills and perform correctly
	Explainer	Goal of instruction is for students to develop conceptual understanding of a unified body of knowledge
	Facilitator	Goal of instruction is for students to become confident problem solvers
Using Technology in the classroom (Goos et al., 2003)	Master	Dependence on technology, not capable of evaluating the accuracy of the output generated by technology
	Servant	Fast, reliable replacement for mental or pen and paper calculations
	Partner	Cognitive reorganization, use technology to facilitate understanding, to explore different perspectives
	Extension of Self	Incorporate technological expertise as a natural part of mathematical and/or pedagogical repertoire

Using Hollebrands and Smith's (2010) rubric, I scored the task-based interview. The rubric was designed to assess participants' content-based TPACK components: CK, PCK, TCK, and TPCK (see Table III - 3). For each of the four tasks, I assigned one of four levels (emergent, beginner, intermediate, or advanced) in the four TPACK components. As an overall level of each TPACK component, I assigned the most frequent level the participant displayed or the middle one when there were three or two different levels. When there were two adjacent levels of knowledge twice, I assigned the level that best captured the participant's level of knowledge.

<Table Ⅲ - 3> Rubric Used to Analyze Technological Pedagogical Content Knowledge Interview Task 1

Content Knowledge	Pedagogical Content Knowledge	Technological Content Knowledge	Technological Pedagogical Content Knowledge
A. Responds that the claim is sometimes true. B. Knowledge that there exists at least one quadrilateral for which the diagonals are not always congruent. C. States that for at least the rectangle and square the diagonals are always congruent. D. Provides a correct mathematical justification for why the statement is sometimes true using proofs that involve triangles or other properties.	A. Identifies that the student is able to notice that for a square and a rectangle that the diagonals are always congruent based on their measures. B. Identifies that the student is at level 2 (descriptive) but probably not at level 3. C. Has students consider at least one counterexample of a quadrilateral that has congruent diagonals. D. Asks students to consider at least one example of a quadrilateral that has congruent diagonals.	A. Accurately constructs or draws a quad that is a counter-example using a dynamic geometry environment (DGE). B. Uses measures to find the lengths of the diagonals. C. Drags to create multiple examples in a DGE. D. Accurate constructions of 2 of the following quads: Square Rectangle Parallelogram Rhombus	A. Uses the DGE technology to focus students on properties of different quadrilaterals and their relationships to the diagonals in the task. B. Creates more than a single example using DGE technology to show the student that they are incorrect in the task. C. Designs an exploration for students by creating accurate constructions and utilizing the measurement and dragging features
Emergent: 0 or no response. Beginner: 1 of A-D Intermediate: 2 of A-D Advanced: 3 of A-D	Emergent: 0 or no response. Beginner: 1 of A-D Intermediate: 2 of A-D Advanced: 3 of A-D	Emergent: 0-1 of A-D or no response. Beginner: 2 of A-D Intermediate: 3 of A-D Advanced: All of A-D	Emergent: 0 of A-C or no response. Beginner: 1 of A-C Intermediate: 2 of A-C Advanced: All of A-C

Finally, the performance interview was scored based on three categories—content, pedagogy, and technology—with four levels (emergent, beginner, intermediate, and advanced). In the content category, I examined whether the participants had mathematical knowledge related to the theorem, a deductive or inductive proof, or connections between mathematical ideas or concepts. In the pedagogy category, I examined what strategies they used to teach the theorem to their imaginary students and whether they could anticipate the students' mathematical thinking or potential difficulties. In the technology category, I focused on the participants' knowledge about GSP. I examined whether they knew how to use GSP to implement certain tasks and how they used technology to support their pedagogical strategies.

IV. Findings

In this paper, I focused on two participants, Doris and Tim, who displayed contrasting beliefs and knowledge about technology use even though they had similar experience, beliefs, and knowledge about mathematics and learning mathematics.

1. Doris

1) Experiences and beliefs about technology use

Doris had little experience with using technology in her mathematics classes in middle school and high school. Her mathematics teachers did not use technology in the classroom, and Doris only used a basic calculator. After entering college, Doris had some opportunities to use different technologies (e.g., internet, graphing calculator, Geometer's Sketchpad, and Smart Board) in mathematics content and methods courses. In mathematics content courses, however, the instructors still did not use technology for mathematical learning. The instructions were usually through lectures that were no different from the traditional classroom. Doris used technology when she needed to communicate with the instructors, such as when asking questions via email.

From those experiences, Doris developed her view of the use of technology in learning and teaching mathematics. She believed technology tools were useful and efficient for learning and teaching mathematics and explained that visualization is one of the good aspects of technology tools. She stated:

> The role of technology in mathematics is help to facilitate the math lessons and make math be more interesting. Using technologies such as Smart Board or videos, students can easily visualize some concepts, such as solving systems of equations by substitution, or listen and see mathematics video so they can be more motivated. It will help them to see the different transformations of shapes in math. Thus, students will see that math does not just contain number and calculation.

However, Doris' overall view of technology was as a Servant: that technologies are quick and accurate tools to replace mental calculations or pen and paper works. Doris believed the use of a calculator hinders students' mental math, and she did not want students to be dependent on technology. She said:

> I will try to avoid students to use calculators every time. I want the student to be able to do some mental math. ... I think calculator ... is just like a tool for the student to learn math faster. ... For all of math class, I just want students to see technology as a tool to learn, not to like rely heavy on it. Not too dependent.

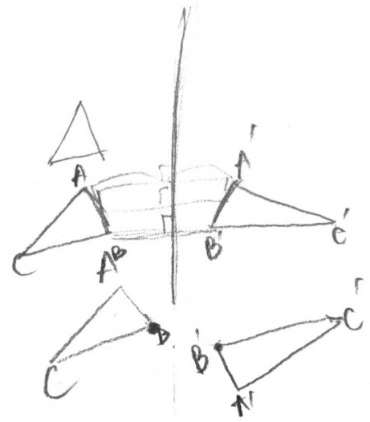
In terms of assessments using technology, Doris only focused on whether technology gives accurate, fair, and quick feedback. She said, "We have a clicker and we enter the multiple choice question, and then after that click the result, it gets back to students quickly. So it's accurate and fair and it saves time for the student." In addition, her description of how she would use Smart Board was more teacher-centered. Doris stated:

> Sometimes students can use the Smart Board, but with the teacher observing them. I don't think students are allowed to jump in Smart Board to write on themselves. ... I use Smart Board for the saving tool, for saving my lecture and lesson. So, if the student uses it, I'll save student work, too. So, if one student uses Smart Board only when they come up and solve the problem, explain the problem. But other than... the graphing work ... I'd rather use the white board.

Doris stated advantages of technology use in mathematics classes at a superficial level. Overall, she seemed to view technology as an add-on that provides visual aspects and quick and accurate answers rather than as an exploring tool that provides various representations of mathematical concepts and facilitates conceptual understanding. Therefore, I coded Doris' view of the use of technology in learning and teaching mathematics as a Servant.

2) Technology-related knowledge

Across the task-based and performance interviews, Doris displayed a Beginner level of TCK. Doris knew how to use basic skills of GSP, such as how to drag points and figures, label points, and measure lengths and angles using GSP tools. However, when thinking about mathematical concepts or demonstrating her knowledge, she did not seem to feel as comfortable when using GSP as when writing on paper. For instance, Doris did not initially know that a reflection line is needed to reflect a triangle when using GSP, even though she correctly drew a reflection line when she drew a triangle and performed reflection on the paper (see Figure IV - 1). In addition, Doris did not know how to construct the reflection line and the extended line of the side of the figure using GSP. During the task-based and performance interviews, Doris seldom used the dragging feature, which is one of the most beneficial features of GSP. She just dragged a point or figure to move somewhere or make it bigger or smaller rather than dragging it with instructional purposes.



[Figure IV − 1] Doris' performance of reflection and a 180 degree rotation of a triangle on the paper

Overall, Doris displayed a Beginner level of TPCK. She was able to create more than one example and task using GSP to show the students that their conjectures are incorrect. In the task-based interview, her tasks, however, did not help students develop their understanding of why their conjectures are incorrect, nor did it deepen their understanding of the mathematical content. In addition, as I stated above, Doris did not use the dragging feature to create multiple examples, explore properties of figures, or examine conjectures. She did not fully use diverse features of GSP. For example, Doris could not design activities in which students would discover what a circumcenter is and its features using a circle and measuring tool of GSP. In the performance interview, Doris' goal of the lesson was to have the students find out whether the exterior angle theorem is true for a polygon, but she just provided directions step by step. Rather than having the students explore many cases to figure out whether the theorem is true or not using GSP, she was only focusing on showing that the theorem is true. In addition, when Doris led the students to come up with the proof of the theorem, she seemed to give them many hints and ask direct questions. For example, she had already showed the students the proof of the theorem for the triangle case and the process of finding the formula for the sum of the interior angles of an n-sided polygon, and she then asked the students a leading question, such as asking what the sum of the exterior and interior angles at the one vertex was and how one could calculate the sum of the exterior angles. Doris seemed to value explanation or transmission of her knowledge rather than students' opportunities to explore and find out why the theorem is true for any convex polygon themselves.

Doris said she would not use GSP to teach the exterior angle theorem for large number sided polygons because she believed that technology should enable students to work quickly, and using GSP when dealing with polygons that had many sides would be time-consuming work. She seemed to believe that explaining processes of proof by hand is a familiar and easier way to teach the theorem than constructing conjectures and exploring many polygons using GSP.

2. Tim

1) Experiences and beliefs about technology use

Unlike Doris, Tim had a lot of experience with using technology in high school. He used a graphing calculator every day in Algebra II and depended on the calculator. One of his mathematics teachers had a Smart Board and often used a projector, as well. In college, Tim used diverse technologies very often (e.g., Fathom, Geometer's Sketchpad, Excel, StatCrunch, JMP, and Smart Board) and liked to use technology in learning mathematics and statistics. Tim seemed to be familiar with various technologies.

When I asked about the effects of the use of technology on students' mathematical thinking and learning, Tim said, "I think it grows…It [technology] makes it [students' mathematical thinking] grow exponentially." He believed that students can find relationships between concepts and derive a theorem or formula by having and moving figures that students can manipulate themselves when using technology, especially GSP. He said, "That's where I feel the conceptual understanding comes in is just by having it and just playing around with it. So technology has improved their thinking way beyond what we did." Tim was willing to use technology for his mathematics instruction because he viewed technology as a huge part of our society: "It just helps the students understand more and makes it a little more flashier." Since Tim believed that a huge advantage of using technology is its use in investigation, he said he would use technology for students' investigations or for big projects. He also wanted his students to use technology freely and find out mathematical concepts themselves. For example, Tim stated:

> To find the relationship between a square and a rectangle, I think I would let them do it themselves. Because that's just clicking, moving, and all that stuff. Like constructions, I would let them do that by themselves ... I would definitely utilize them using it by themselves.

In addition, Tim thought technology made teaching easier than before, not because technology is fast or replaces pen and paper work, but because technology helps students understand conceptually. He explained:

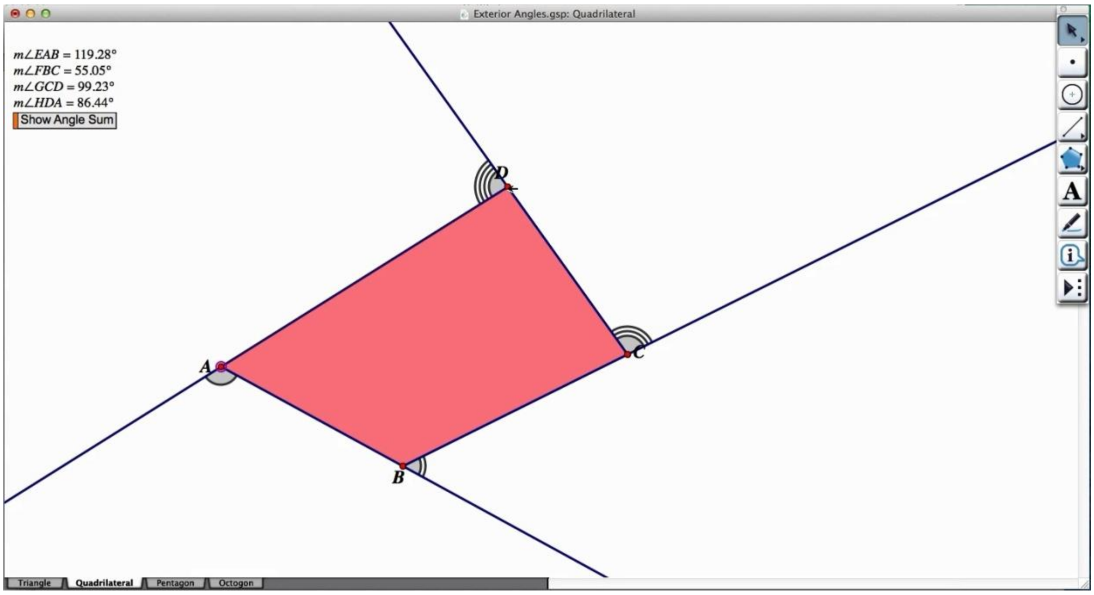
> Students will love it [technology] and it will make our job ten times easier. Because then we might not have to go back ... we might not have to spend as much time teaching the subject as students might now start to conceptually understand it more.

Therefore, I characterized Tim's view of using technology in learning and teaching mathematics as a Partner.

2) Technology-related knowledge

From my analysis of his task-based and performance interviews, Tim displayed an Advanced level of TCK. He was able to use the measuring, labeling, and dragging features of GSP. Tim especially used the dragging feature for diverse purposes. He dragged a point or figure to make many examples and explore the properties of quadrilaterals, rotation, and reflection. Tim also used the dragging feature of GSP to find a pattern of the location of the intersection of perpendicular bisectors of a triangle. Tim was able to construct different quadrilaterals and perform a rotation. In addition to constructing tools, which are used when constructing mathematical figures, Tim knew how to use supportive tools of GSP, which are not directly related to mathematical features. For example, he was able to add pages on the GSP file and make buttons that show or hide figures, measurements, or captions (see Figure IV - 2).

Tim's overall level of TPCK was Intermediate. Tim demonstrated that he could provide many examples and design exploratory tasks that help students recognize whether their understanding of mathematical concepts is not correct by using various features of GSP. In the performance interview, Tim tried to ask many questions to facilitate the students' exploration rather than just giving them the answers. He would let the students use diverse tools of GSP themselves, such as constructing, dragging, measuring, and calculating tools. He thought that the use of GSP would add more fun because the students could work with their own figures and actually see that the theorem works for any convex polygon. Tim believed that students should explore diverse mathematical concepts themselves and that technological tools enable them to have those opportunities by providing various representations of mathematics. He also knew how to construct and represent mathematical figures or concepts using diverse features of GSP. His lack of content knowledge, however, seemed to be a barrier to using GSP effectively to teach mathematic concepts. For example, in the task-based interview Tim did not know that the intersection of perpendicular bisectors of a triangle is a circumcenter, so he could not measure the distances from the circumcenter to each vertex of a triangle and construct a circumscribed circle using GSP to help students discover the properties of a circumcenter. Although his tasks were usually student-centered activities, some of his tasks did not lead the students to deeper understanding or justifying why their claims were true or false.



[Figure Ⅳ − 2] Tim's pre−constructed GSP file for teaching the exterior angle theorem

Ⅴ. Discussion and Implication

In this paper, Doris' and Tim's knowledge and beliefs about the nature of mathematics and learning mathematics were not discussed in detail. In brief, Doris and Tim had the same levels of CK and PCK and similar beliefs about mathematics and learning. They defined mathematics as both a set of facts and rules and a unified body of knowledge that does not change simultaneously. They also tended to view learning mathematics as a passive reception of knowledge. In addition, Doris and Tim had very similar experiences in mathematics classrooms in middle school and high school. They were taught mathematics in a traditional way. For example, their mathematics teachers lectured and had them memorize mathematical formulas and repeatedly solve the same types of problems. Although Doris and Tim had similar knowledge, experiences, and beliefs about mathematics and learning, their levels of TCK and TPCK were quite different. It is possible that Doris and Tim had different experiences in terms of their access to technological tools and their uses in mathematics classrooms, and it also related to their different beliefs about technology use. Doris' limited experiences with technology formed her technology-related beliefs that technology can be only used for quick and accurate calculations under the control of a teacher. As discussed by Crompton (2016), her traditional beliefs and lack of experience with technology seemed to influence her low level of TCK and TPCK. On the other hand, Tim, who had a lot of experience with using diverse technological tools in mathematics classrooms, formed positive and student-centered beliefs about technology use and displayed higher levels of TCK and TPCK than Doris. His experience and beliefs seemed to influence his technology-related knowledge. Thus, having a lot of positive experiences with using technology in mathematics classrooms and holding student-centered beliefs about the use of technology for mathematics learning and teaching are significant factors on the levels of technology-related knowledge and the use of technology. This result is consistent with the findings of Ottenbreit-Leftwich et al.'s (2010) study that teachers' beliefs related to technology use have an impact on the use of technology in their teaching.

The findings of this study suggest what aspects mathematics teacher educators (MTEs) should consider to develop preservice mathematics teachers' effective technology integration. Although I only focused on preservice teachers' beliefs towards and knowledge of the use of technology in mathematics classrooms in this paper, the results of this study still provide evidence that preservice secondary mathematics teachers' beliefs and knowledge about technology integration are closely related and influence each other. Therefore, MTEs should focus on helping preservice teachers understand that as a tool for learning and teaching mathematics, technology has strong potential in developing students' mathematical thinking and understanding (정인철, 오세열, 2001). Also, MTEs should provide learning and teaching experiences with student-centered approaches and positive experiences with technology and training to integrate technology into mathematics instruction in order to develop their levels of TPACK.

As only four preservice teachers volunteered for this study and I focused on two preservice teachers, the results of this research are limited in generalizability. Thus, future studies with larger samples are needed. In addition, conducting the study in different mathematical contexts, such as algebra and statistics, may provide different results and further insights into the relationships between preservice teachers' beliefs and TPACK.

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예비 교사의 수학 수업에서 테크놀로지 사용에 관한 경험과 신념이 그들의 테크놀로지 관련 지식에 미치는 영향

김소민[2)]

초록

교육에서의 테크놀로지 사용으로 인한 혜택과 이에 대한 관심이 커지면서, 테크놀로지를 통합한 수학 수업에서 교사의 역할이 더욱 중요해졌다. 따라서 예비 교사의 기술적 교육학적 내용 지식 (Technological Pedagogical Content Knowledge: TPACK)을 발전시키는 것이 중요하며, 이는 그들의 신념에 영향을 받는다. 본 연구에서는 예비 고등 수학 교사들의 수학 수업에서의 테크놀로지 사용에 관한 경험과 신념이 그들의 TPACK에 어떻게 영향을 미치는지 조사 하였다. 연구 결과, 테크놀로지 사용 경험이 많고 학생 중심적 테크놀로지 사용에 관한 신념을 가진 예비 교사들이, 경험이 적고 교사 중심의 신념을 가진 예비 교사들 보다 테크놀로지에 관한 지식이 높은 것으로 나타났다. 예비 교사들의 TPACK과 신념의 관계에 대한 이해는 예비 교사들이 TPACK을 발전 시키고 테크놀로지 통합 수업을 할 수 있도록 하기 위해, 교사 교육 프로그램이 어떻게 지원 해야 할 것인지에 관한 통찰을 제공한다.

주요 용어: TPACK, 예비 고등 수학 교사, 교사의 신념, 동적 기하학 환경(dynamic geometry environment)

투고일 2016년 11월 21일
수정일 2016년 12월 22일
게재확정일 2016년 12월 22일

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