DEVELOPING TPACK ALONGSIDE PROFESSIONAL VISION OF TEACHING MATHEMATICS WITH TECHNOLOGY

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This study questions the extent to which a course in Mathematical Problem Solving with Technology was developing TPACK in mathematics preservice teachers. In order to measure the development of TPACK, both quantitative and qualitative data were collected. Preliminary findings are promising. Preservice teachers developed a vision of technology use in the classroom that better aligned with the vision outlined in the NCTM Technology Principle. Students reported they had sufficient opportunities to work with different technologies throughout the course. Moreover, students reported they could choose technologies that enhance the mathematics for a lesson.

Keywords: Teacher Education–Preservice; Technology; Problem Solving

Introduction

In seminal works (Niess, 2005, 2008; Mishra & Koehler, 2006) that have culminated in the description of a framework by which to study the development of Technology, Pedagogy And Content Knowledge (TPACK), mathematics teacher educators have envisioned teacher education programs that integrate technology instruction with content and pedagogy. These programs would provide preservice teachers with learning opportunities that might help them amend personal philosophies of teaching to reflect a deep understanding of teaching with technology. A picture of how to accomplish this integration is emerging in the field, including Zbiek and Hollebrands' (2008) position that the ways in which technology is integrated into teachers' classrooms is influenced by their conceptions of technology, mathematics, learning and teaching. Furthermore, Zbiek and Hollebrands (2008) recommend that preservice teachers be given opportunities to use technology as a mathematics learner and then reflect on those experiences from a pedagogical perspective.

We have begun to develop our own vision of what it means to enact these principles in the development of preservice secondary mathematics teachers (PSMTs) and to honor the rich connections between technology, mathematics, and teaching. This paper reports on a study of 39 PSMTs enrolled in two sections of a course, *Mathematical Problem Solving with Technology*. In this course, PSMTs are expected to revisit their own learning of secondary mathematics and investigate mathematical concepts by way of problem solving with various technological tools. Taught with an eye toward immersion learning, the PMSTs in our course are engaged almost entirely in lab-based activities and discussion of the mathematical, pedagogical and technological principles they encounter along the way.

Methodology

As a means to inform our own practice, we engaged in research to uncover the extent to which our course was supporting the development of TPACK in our preservice teachers. We set about to explore two research questions: (1) What is the vision of teaching mathematics with technology held by PSMTs prior to and at the conclusion of a semester of concentrated experiences utilizing technology for mathematical problem solving? (2) To what extent does our course influence TPACK of our PSMTs?

Participants and Setting

The participants of this study were enrolled in a semester-long course, *Mathematical Problem Solving with Technology*, during the 2010-11 academic year. PSMTs pursuing licensure to teach secondary mathematics typically take this course during their sophomore year. As our PSMTs enroll in the majority of their education courses in the junior year, those enrolled in this course have not yet taken any methods

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courses or completed any field placements in a K–12 setting. Of the 39 participants, three had graduate student standing but had not taught secondary mathematics at the beginning this course. During the fall semester, 18 participants were recruited and during the spring semester, 21 students were recruited.

Data Collection

Data were collected with the purpose of measuring the development of TPACK as well as linking that development to practice. In order to accomplish this goal, two distinct perspectives were taken. First, we wanted a quantitative tool by which to capture growth in TPACK over time. We selected a survey intended to measure TPACK (Zelkowski et al, under review) and administered it as a pre/post measure during the first and last weeks of the course. The survey is divided into multiple sections with items assessing each of the domains within the TPACK framework, but we chose to focus our analysis on six items shown to be reliable and valid in measuring perceptions of TPACK (Zelkowski et al, under review).

Table 1: Summary of Selected TPACK Survey Items

Item	Prompt
Item 1	I can use strategies that combine mathematics, technologies, and teaching approaches that I learned about in my coursework in my classroom.
Item 2	I can choose technologies that enhance the mathematics for a lesson.
Item 3	I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn.
Item 4	I can teach lessons that appropriately combine mathematics, technologies, and teaching approaches.
Item 5	I can teach lessons that appropriately combine algebra, technologies, and teaching approaches.
Item 6	I can teach lessons that appropriately combine geometry, technologies, and teaching approaches.

It was also important for us to take a deeper look at individual development throughout the course in order to index any global shifts in TPACK to specific facets of the course. In order to examine the opportunities we were providing our students to develop TPACK and to more closely examine any shifts in TPACK that were captured by the survey, samples of student reflective writing were collected of which two samples were used in the current analysis.

Principles of Mathematical Problem Solving with Technology. Within the first month of the course, students were asked to read three items and write a reflection paper. The three items were selected to convey to our students the underlying principles of the course. First, we selected the NCTM Technology Principle (NCTM, 2000). Second, we selected two chapters from *Teaching Mathematics through Problem Solving K–12* (Schoen & Charles, 2003). The chapter written by Hiebert and Wearne (2003) was selected for its overview of problem solving and the vision it provided of teaching and learning. The chapter written by Zbiek (2003) was selected for its attention to the role of technology in a classroom where problem solving is valued. Students were asked to respond to three prompts:

1. *How is the perspective taken in the readings similar or different from your own experiences learning mathematics?*
2. *How does it compare to your own beliefs about teaching?*
3. *What ideas did you find yourself (dis)agreeing with?*

Final Examination. A final examination prompt was provided asking students to describe their vision of responsible use of technology in the classroom.

> *Many of you have reflected on the use of technology in mathematics education and used a statement similar to, "technology is a benefit to the mathematics classroom as long as it is used responsibly." Reflect on this statement and explain to me what "responsible use of technology" looks like in the mathematics classroom. Do not define it in terms of what it is NOT—I am not interested in hearing about examples of irresponsible uses of technology and these will detract from your answer. Instead, use your experiences and any readings you have completed for this class to craft a reasonable*

definition or standard by which I could determine if technology were being used to support teaching and learning of mathematics in your classroom.

This prompt was devised in response to themes identified in classroom discussions throughout the semester. It is not uncommon for PSMTs to begin to categorize their experiences, both past and current, as appropriate/inappropriate. In both semesters, PSMTs invoked the phrase "responsible use" to differentiate between technology practices that they endorsed ("responsible") and those they did not ("irresponsible"). This prompt was aimed at assessing PSMTs' outgoing vision of "responsible use."

Data Analysis

Analysis of written reflection. The two reflections described in the previous section were chosen because of their timing, one in the fifth week of the semester and the other at the completion of the course. Furthermore, the nature of the assignments has the potential to illustrate changes in our PSMTs' visions of teaching mathematics with technology.

Both top-down methods (Miles & Huberman, 1994) and grounded theory (Strauss & Corbin, 1990) were used to develop and apply a coding instrument. Within NCTM's Technology Principle (2000) and also Zbiek (2003), there are many smaller statements about the envisioned role of technology in the mathematics classroom. From these sources, we created a framework by which to analyze the vision our PSMTs held of teaching mathematics with technology. From each statement indicating a potential role for technology, a code was developed. For example, the statement "With calculators and computers students can examine more examples or representational forms" (NCTM, 2000, p. 23) yielded two initial codes, "Examples" and "Representational Forms." While Doerr and Zangor (2000) classified calculator use into five broad categories: Computational, Transformational (changing the nature of the task), Data Collection and Analysis, Visualizing, and Checking (confirming conjectures, understanding multiple symbolic forms), we initially identified 25 specific roles technology plays in the classroom. We later refined this list to 17 as coding progressed, including combining "Representational Forms" with "Visualization," as it was difficult to parse out differences such as this in our PSMTs' writing. The final list of codes is listed in alphabetical order in Table 2.

Table 2: Framework for Examining *Vision of Technology for Teaching*

Perceived Roles of Technology in the Mathematics Classroom		
Assessment	Exploring Conjectures	Problem posing
Communication	Extends Range of Problems	Problem Solving/Reasoning
Differentiated Learning	Mathematical Change	Reflection
Efficiency/Accuracy	Mathematical Connections	Supplementation
Engagement	Organize/Analyze Data	Visualization/Representational Forms
Examples	Present/document	

TPACK surveys. Pre- and post-survey data were collected and analyzed to determine overall shifts in perceived TPACK amongst PSMTs taking a semester-long course in problem solving with technology. In order to compare the results of the administrations of the TPACK survey, individual scores were tabulated by summing the responses given by an individual to each of the six items in terms of the 5-point Likert scale values (1 = Strongly Disagree, 5 = Strongly Agree). Quartile scores for each administration were calculated and compared using a box-and-whisker plot. In order to delve deeper and assess growth with individual items, a novel data visualization was constructed utilizing color as a means to assess the extremity of individual responses as well as the overall change in PSMT responses between administrations. A detailed description of this data visualization is provided along with the results of the analysis.

Results

In response to the research questions outlined above, the results will be organized in three distinct sections. First, we will present the results of the qualitative analysis of the two collected samples of reflective writing. Then, we will present the results of a quantitative analysis of the TPACK survey data.

Incoming Vision of Teaching with Technology

Utilizing the framework in Table 2, we coded each of PSMT's reflections on the role of technology in the teaching and learning of mathematics. While we could recognize at least one of the roles in most of the reflection papers, there were two reflection papers that received zero codes. These two PSMTs did not share a vision with regard to the inclusion of technology in the classroom. One stayed close to a positive, yet non-specific message, that technology should be used to enrich the students' experience, while the other challenged the essentiality of technology in the classroom altogether, stating:

> *Why is it so essential, as described in the Technology Principle, that technology be used in the application and problem solving of math (NCTM, 2000)? My thought is that shouldn't anything in math class be able to be solved without the aid of technology?*

In the remaining 37 reflections, we were able to recognize anywhere between one and nine of the roles (and on average 3.35), whether the PSMT agreed, disagreed or simply summarized the author's position. The most-agreed-with roles include Supplementation (49%), Efficiency/Accuracy (36%), Problem Solving/Reasoning (28%), and Visualization and Representational Forms (41%) (see Figure 1 [red columns]). Of the 17 roles, some seemed to garner more argument than others. Engagement (33%), Visualization/Representations Forms (41%), and Mathematical Change (13%) were mentioned more than most of the other roles both positively and negatively. While 33% of our students agreed that technology engages students, 10% disagreed, claiming technology was a distraction. Walter calls some of the statements made in the Technology Principle "too sweeping" and explains,

> *I submit that if a student is not motivated by the task at hand, then a computer provides many more distractions for them. This is not to suggest that one should not use a computer, only that I disagree with the implication that utilizing a computer task is a cure for those that are easily distracted.*

While this provides a snapshot of the specified vision our PSMTs had at the start of the semester, there was also an undercurrent of concern about the use of technology in the classroom in general. The most common concern was that technology would prevent students from achieving mastery of mathematics. More than 25% of our students specifically mentioned their concern that students will either miss out on learning basic skills (generally arithmetic) or that this knowledge initially gained will atrophy once technology is in hand. Even more expressed concern that technology would replace a student's basic understandings of mathematics, with 49% choosing to quote, paraphrase or reinterpret the statement, "technology should not be used as a replacement for basic understandings and intuitions; rather it should be used to foster the understanding and intuitions," (NCTM, 2000, p. 24). This was, by far, the most cited passage in all three readings. In addition to these concerns, some PSMTs expressed a sense of nostalgia and favored tradition over technology. Mary says, *"I got through all of those high school courses with just a graphing calculator and passed with flying colors, so why do we need all this technology in our classrooms now?"* This narrow view of education based on personal success or failure permeates the initial reflection papers and causes many to question NCTM's assessment of technology as *essential* in the classroom. A student who feels that they have achieved success in school mathematics potentially sees himself or herself as a counterexample to the essentiality of technology. There is a general reluctance to consider what experiences they may have missed and to judge their own stories as complete and representative of mainstream.

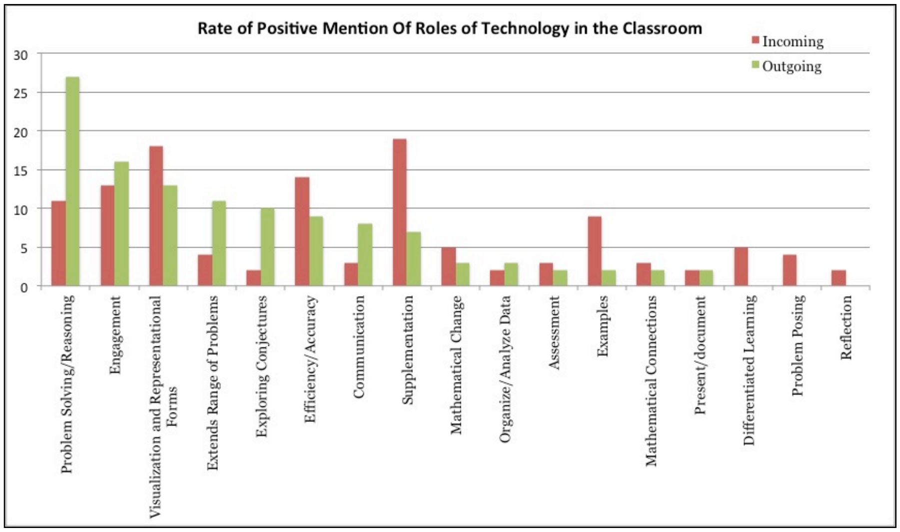

Figure 1: Incoming vision (red) and outgoing vision (green) of teaching with technology

Outgoing Vision of Teaching with Technology

In order to gauge the vision of teaching with technology that our PSMTs had when they exited our course, we conducted a similar analysis of their responses to the Final Examination Prompt. In this assignment, our PSMTs were explicitly asked to share their vision of "responsible use of technology in the classroom." In this sense, the assignment was different from the first reflection in that the PSMTs were not asked for their reactions to an expressed vision, but rather to create their own.

Unlike their initial reflections, every PSMT identified at least one specific role that technology plays in the mathematics classroom. On average, students identified three roles with the maximum being eight. Figure 1 (green columns) is a depiction of the overall vision. Again, if we take a look at the most identified roles, we get an indication of the vision of the group. Almost 70% of our PSMTs made mention of the role technology plays in problem solving and reasoning in the classroom. Engagement, Visualization and Representational Forms, Efficiency/ Accuracy and Supplementation are still among the most cited. However almost three times as many PSMTs as did initially indicated technology extends the range of problems that can be used in the classroom and aided in Communication, and five times as many noted technology could be used to Explore Conjectures. The number of students who indicated technology should be used to supplement pencil-and-paper instruction dropped by a factor of three.

TPACK Survey Data

In order to compare the results of the administrations of the TPACK survey, individual scores were tabulated by summing the responses given by an individual to each of the six items in terms of the 5-point Likert scale values (1 = Strongly Disagree, 5 = Strongly Agree).

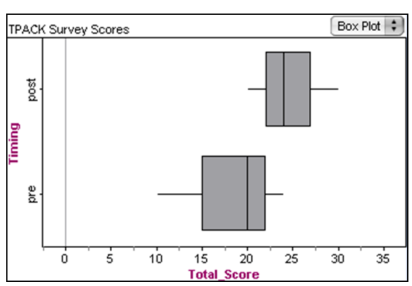

Figure 2: Box plot with whiskers comparing TPACK scores for two administrations

These ordinal data are displayed in a box and whiskers plot in Figure 2. The median score increased from 20 on the pre-survey to a 24 on the post-survey. Furthermore, the first quartile of the post-survey and third quartile of the pre-survey are equal, implying that 75% of the post-survey scores were higher than 75% of the pre-survey scores.

To get a deeper sense of these shifts, we composed a color-coordinated image of the data set. The individual responses to each item given on the pre- and post-survey are shown in Table 3. Each row pertains to an individual PSMT and the rows have been sorted in decreasing value according to the sum of the Pre-test scores. The left table contains data collected by the pre-survey. The middle table contains data collected by the post-survey, and the right table contains calculated differences indicating shifts in responses. These were calculated by subtracting pre-survey responses from post-survey responses. Due to page limitations, we have provided only a portion of the table to give the reader a sense of the trends in the data.

Table 3: Color-Coded TPACK Survey Where Individual Responses Have Been Highlighted

Student	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Total (Pre)
1	5	5	4	4	3	3	24
3	4	4	4	4	4	4	24
Stephanie	5	4	4	4	4	2	23
Walter	3	3	2	2	3	3	16
21	2	2	2	3	3	3	15
22	3	2	2	3	2	2	14
24	2	2	2	3	2	2	13
Hannah	2	2	2	2	2	2	12
Wilma	2	2	2	2	2	2	12
26	2	2	2	2	1	1	10
Overall Means	**3.4**	**3.2**	**3.1**	**3.3**	**3.0**	**2.7**	**18.7**

Student	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Total (Post)
1	5	5	5	4	5	5	29
3	4	4	4	3	3	4	22
Stephanie	5	5	5	5	5	5	30
Walter	5	5	5	5	4	5	29
21	4	5	5	5	5	5	29
22	4	4	4	4	4	4	24
24	4	5	5	4	4	4	26
Hannah	4	4	3	4	4	4	23
Wilma	3	4	4	3	4	4	22
26	4	4	4	3	4	4	23
Overall Means	**4.1**	**4.3**	**4.2**	**3.9**	**4.0**	**4.0**	**24.5**

Student	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Difference
1	0	0	1	0	2	2	5
3	0	0	0	-1	-1	0	-2
Stephanie	0	1	1	1	1	3	7
Walter	2	2	3	3	1	2	13
21	2	3	3	2	2	2	14
22	1	2	2	1	2	2	10
24	2	3	3	1	2	2	13
Hannah	2	2	1	2	2	2	11
Wilma	1	2	2	1	2	2	10
26	2	2	2	1	3	3	13
Overall Means	**0.7**	**1.1**	**1.1**	**0.7**	**0.9**	**1.3**	**5.8**

In each table, color has been used to visually differentiate the responses with the more saturated colors indicating more extreme views. In the first two tables, green (responses 4 & 5) indicates that the student has agreed with the prompt and red (responses 1 & 2) indicates that the student has disagreed with the prompt. White (response 3) would indicate a Neutral response. In the final table, green (positive integers) indicates a positive shift while red (negative integers) indicates a negative shift.

Interpreting the tables means looking at how the color patterns change. If we compare the pre-survey and post-survey scores from all 29 participants, we find dramatic color shifts. The cloud of red at the bottom of the pre-survey data disappears in the post-survey data and is replaced by light green and even some dark green cells. At the top of the tables, we see a dark green cloud emerge in the post-survey data replacing the light green and white that was present in the pre-survey data. Red and pink have virtually disappeared from the post-survey data, demonstrating that PSMTs disagreed with very few prompts after the course had completed.

This is also reflected in the overall color tone of the difference table, which is almost entirely composed of white and shades of green. Very few items showed a negative shift from pre-survey to post-survey, and these are indicated by the pink cells.

Findings and Implications

This study seeks to further the research in the field of TPACK by testing the hypothesis set forward by Zbiek and Hollebrands (2008) that a key experience for PSMT should be to use technology as a mathematics learner and then reflect on those experiences from a pedagogical perspective. Our results show that a course in Problem Solving with Technology that provides opportunities for PSMTs to reengage with school mathematics using a problem-based curriculum in a technology-rich environment has

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a positive impact on PSMT TPACK development as well as on PSMTs vision of teaching with technology. This vision was communicated in part by examining specific experiences and readings encountered during the course and presenting them as illustrating examples of what the 'responsible use' of technology looks like in the classroom. We find that we can draw two conclusions.

Finding 1: Our students developed a vision of technology use in the classroom that better aligned with the vision outlined in the NCTM Technology Principle. If we take a closer look at the nature of the roles that we were able to identify in the incoming visions of PSMTs, Supplementation (49%), Efficiency/Accuracy (36%), and Examples (23%) are roles that suggest our PSMTs are envisioning technology as "computational" tools rather than "transformational" or "visualizing" tools (Doerr & Zangor, 2000). In contrast, we find the roles of Visualization and Representational Forms (41%) as well as Problem Solving/Reasoning (28%). This may be due to the brief exposure our PSMTs had to problem solving using dynamic geometry software in the five weeks prior to the submission of this reflection. It was clear that many were enamored with the ability to generate dynamic geometric objects for study and had begun to envision their personal independence in mathematical problem solving. It is likely that even this brief exposure had an impact on the PSMTs' vision. It is unclear whether that vision was truly aligned with that of NCTM, but many referenced these roles positively. Whereas their initial vision favored using technology to "do mathematics", the outgoing vision seems to favor technology for learning mathematics. PSMTs more readily identified roles that were "transformational" or "visualizing" (Doerr & Zangor, 2000). Furthermore, PSMTs readily accepted the role technology plays in generating and sustatining classroom discussion of mathematics and collaborative work habits, something that was missing from their initial vision.

Finding 2: A course in problem solving with technology can have an impact on the TPACK development of PSMTs. The results of our analysis of pre- and post-survey data show a clear increase in the TPACK of our PSMTs. The items that saw the greatest gains were, "*I can choose technologies that enhance the mathematics for a lesson," "I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn,"* and, *"I can teach lessons that appropriately combine geometry, technologies, and teaching approaches."* Comments made in their final exam reflections would support this finding as well. It is clear that PSMTs are thinking more about what it would take to enact their vision of teaching with technology and the complexity of that practice.

Conclusion

Many factors affect the development of PSMTs' use of appropriate technology tools. Olive and Leatham (2000) have documented that using technology as a tool for learning mathematics is not enough to ensure PSMTs will use technology as a teaching and learning tool in their own classrooms. Many PSMTs need sustained interactions with technology throughout their teacher education programs, especially in the context of content and pedagogy courses, combined with positive experiences that would challenge their deeply rooted beliefs. However, unless students are given opportunities to reflect on their beliefs and come face-to-face with them, it will be difficult for them to relinquish their fears and mistrust (Fleener, 1995).

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