The Modern Geometry Course Works Overtime: Preservice Teachers Learn Content and Technological Pedagogical Content Knowledge with Geometer's Sketchpad.

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Abstract

The concept of Technological Pedagogical Content Knowledge (TPCK) is used to describe what teachers need to know in order to effectively integrate technology into their teaching practice (Mishra & Koehler, 2006). A current issue facing teacher education programs is the task of preparing mathematics teacher candidates to teach with a high level of TPCK, Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK) (Niess, 2006). Teacher education programs have the option of creating and teaching stand alone technology courses, where students learn how the technology works, or they can opt to integrate the use of technology into the mathematics content courses. The major benefit of integrating technology use into the mathematics content course is that it places the teacher candidate in a setting where the constructs of TPCK, TCK, and TPK are modeled by an expert practitioner and, equally important, the teacher candidate gains experience using technology as a tool to learn mathematics. This paper will document evidence of TPCK in the current teaching practice of recent graduates of a technology intensive modern geometry course.

Introduction

Lampert and Ball (1999) report that professional preparation of new teachers is often of little use or practicality and that "student teachers are often most influenced by what they see their cooperating teachers do or by their own memories from school (p. 39)." Thus to prepare P-12 teachers to teach well, with technology, university professors of content courses should do the same. As a former high school teacher I used both Logo and Geometer's Sketchpad (GSP) to teach geometry. My approach was to design activities that would guide the student to a conjecture that could then be proven. The ability to plan for and teach effectively with technology has been identified as Technological Pedagogical Content Knowledge or TPCK (Mishra & Koehler, 2006; Niess, 2005). When technology is added to the teaching and learning environment teachers need to possess technological content knowledge (TCK), which is manifest when a teacher can select an appropriate task from the geometry curriculum to be performed with the aid of technology with the goal of student understanding. In addition to a high level of technological content knowledge, effective instruction with technology requires new forms of technological pedagogical knowledge (TPK); including creating and maintaining the learning environment, employing a variety of instructional strategies, and facilitating discourse in the classroom.

Over the past few years I have taught four sections of college geometry (at two different institutions) with two overarching technology goals: to incorporate Geometer's Sketchpad to facilitate content mastery and to model for future teachers the appropriate use of technology for investigating and learning mathematics. The question that sparked the study reported here is "What evidence, if any, exists in the current teaching practice of my former students that indicates appropriate teaching with technology or TPCK?"

The Modern Geometry Course

I first encountered a technology enhanced college geometry course as a doctoral student at Western Michigan University (WMU). The course was designed by Tabitha Mingus and was situated in a Mac computer lab. I observed a section of the course and then taught the course the following year under the supervision of Mingus. Throughout the semester students completed a number of discovery type GSP labs that were created by Mingus. The text used was *Modern Geometries* (Smart, 1998). The course covered finite geometries, Euclidean geometry and the parallel postulate, before progressing to non-Euclidean geometries and then fractals. One particular sequence of lab activities required students to create the Euler line in Euclidean geometry and then, later in the semester, decide if this type of line could or could not exist in hyperbolic geometry. The hyperbolic plane could be effectively modeled using a Poincaré disk model and hyperbolic tools which were available through the textbook's support website.

In 2002 I began teaching at a small Christian liberal arts college. In the fall of 2003 I taught the Modern Geometry course using the same topic progression, same text book, and borrowed heavily from the labs that Mingus had created to infuse the course with discovery activities using GSP. Of a total of nine students in the 2003 course, seven were mathematics education majors.

Methodology

To examine the question "What evidence of TPCK exists in the teaching practice of my former students?" I contacted students from the 2003 Modern Geometry cohort. Of the seven mathematics education majors, five were teaching public high school at the time of this study. Four of the graduates agreed to complete a survey and interview. The technology survey was used, with permission, from Rose Cavin's doctoral work (unpublished at this time). The semi-structured interview progressed from "use of technology as an undergraduate" to "use of technology as a teacher." The questions were not specific to GSP and included a variety of technologies including graphing calculators, PowerPoint, the worldwide web, and spreadsheets. The goal was to flesh out the teachers' reflections on using GSP as an undergraduate and the impact this experience may have had on their current practice. The teachers also granted me access to their undergraduate work. The interviews were audio taped and later transcribed. The interviews were then coded using the TPCK framework (Mishra & Koehler, 2006) along with emergent coding to reveal common themes. When direct quotes from the interviews are used below the line numbers are referenced from the respective transcript.

Results for Lee and Mary

The four teachers fell into two distinct groups delineated by their current involvement with GSP as well as their content knowledge levels as undergraduate students. The first group included Lee and Mary (pseudonyms used). Neither of these teachers used GSP for personal or classroom work and both teachers received grades lower than an A in the Modern Geometry course. These teachers both reported a low level of technology use in their respective classrooms. Lee taught low-level algebra I and Mary taught algebra I and II. Lee reported using PowerPoint about once a month and used the Internet to find supplemental lesson materials. Mary reported using spreadsheets for a student grade book, after her father helped her design a template. Both teachers reported minimal use of graphing calculators with their students.

Current use of Technology

When Lee was questioned about technology use in his current teaching practice he cited the use of two different programs. In the interview Lee stated that he used Plato the most, with the goal of review and test preparation. He also reported using a program called Quizdom. The way

Lee reported using this particular program hints at his developing level of TPCK. He first reported using it for review and then progressed to using the questions to lead students through the development of content knowledge. About his use of Quizdom, Lee stated:

> There is a classroom set of remotes [clickers] for the students, there's a teacher remote and what I use it for, is for review, mainly as review. I have introduced lessons with it. ... I give them a bunch of questions that they should know. Then I started giving them questions that they were going to learn about, but it followed the question before it. So if they applied what they knew in the question before it they could make the next step into what we were going into, a theory we were going into (lines 179-184).

Lee explained that as he became more comfortable with the program he began to select questions that would guide the lesson instead of just review the content. Lee also explained the learning process he experienced when he had to preset the time students were given to answer or "click." Given too little time, Lee's students were frustrated, but when given too much time they got off task. In this example TPCK was also illustrated by how wait time was dependent on the intersection of Lee's knowledge of the question (content), his understanding of student knowledge and learning (pedagogy), and his knowledge of the software (technology).

Mary, the second teacher in this group, allowed students to use graphing calculators in her algebra classes but in the interview she reported teaching only one technology dependent lesson over the past two school years. Mary introduced the concept of a system of linear equations in Honors Algebra I. Mary describes this lesson:

> I did use [technology] to introduce the systems before [teaching it by hand], because they knew how to graph a line. So then I put it into, ok, this is how you use the calculator. Now you graph these two and see where they touch. You know, then [we] talked about how it's called a system and that's your solution, so they could say 'oh, ok now I know how to use the graphing calculator and I understand that that's what the solution is for the problem' (lines 86-90).

Two specific actions from this lesson indicate a high level of TPK. Mary grouped her students for this lesson "partially because we didn't have enough calculators for everybody and partially just so that they weren't completely left alone on what button to press next and so they could help each other (lines 133-135)." She also walked around the room a lot to watch them and help troubleshoot when problems arose. An indication of Mary's TCK was revealed when she commented on the fact that she had to teach the math and how to use the calculator at the same time. "Probably one third of it was the calculator and two thirds was the math (line 111)."

Future use of GSP

On the survey and in the interview, Lee reported a low-level of confidence in his use of GSP and frustration when using it in the Modern Geometry course. What is most interesting is the fact that Lee responded AGREE to the statement "It is important to incorporate GSP in the classroom." Lee shared that he would be teaching a low-level geometry lab course in the fall and that he had already been looking at some GSP activities to use. Of these plans, Lee said, "I happened to browse through the teacher manual yesterday ... And, yea there was just some different activities that I thought, um, I would like to try that. I'm gonna have to try it before, try it before we do it in class (lines 153-156)." Lee also indicated that the frustration of learning GSP as a student was worth it since he was now considering using the program in his teaching.

Mary differed from Lee in her confidence in using GSP both personally and with a class. "I feel very confident, I think I definitely will [use GSP]. We have the computers and the program here (line 40)." Mary went on to say "If I taught geometry (we have GSP and I know another teacher that uses it a lot, but I don't teach it) … but I would be ok using it, because of that Modern Geometry [class] (lines 17-18)."

Perception of GSP

One interesting theme emerged in the data from Lee and Mary. Both teachers perceived that GSP could be used only in geometry. They were not aware of the fact that GSP could be used to graph functions on a coordinate grid with direct applications to teaching and learning algebra. When this realization was raised at the end of the interviews both Mary and Lee felt they should investigate this possibility and requested further information from me.

Discussion

Results of the surveys and interviews with Lee and Mary revealed only glimpses of TPCK. One possible explanation could be that Lee and Mary were not particularly strong in their undergraduate mathematics coursework. This result indicates the importance content knowledge may have on the TPCK framework. Another explanation is that neither of these teachers had been teaching geometry where their TPCK could have developed with the possible use of GSP.

Results for John and Beth

The second pair of teachers included John and Beth. These teachers reported using technology on a daily basis and both excelled in their undergraduate mathematics coursework. John taught the first year of a low-level, two-year geometry sequence and regular geometry. John did not have access to GSP at his school. Beth taught Honors Geometry, Algebra I, and Pre-Calculus and had access to GSP.

John

John, categorized as exhibiting a high level of TPCK, reported a high level of technology use:

> I use PowerPoint everyday to display warm-up problems and practice problems, for examples and activities. The Internet is used as a demonstration tool, but also as a discovery tool for students to research math topics and projects related to areas of interest in their own lives. I enjoy using the graphing calculators (survey).

In the interview John expanded on how one project he created required students to use the Internet to explore platonic solids and another for which they found right angles in real life. One of John's survey responses indicated high levels of TCK and TPK:

> I have prepared GSP materials to use in discovery type lessons; however, I am still waiting on the program to arrive [John co-authored a grant proposal to purchase and integrate GSP into his course]. I currently use it [personal copy] to create diagrams for worksheets or PowerPoint's. GSP is a wonderful program for having students construct or discover their own understanding of geometric principles in an appropriately guided context (survey).

Creation of the GSP materials by John demonstrated his TCK. Using GSP in a discovery or "appropriately guided context" indicated John's understanding of how the learning environment needs to be managed when technology was used (TPK).

Beth

In the survey Beth summarized her current technology use as follows.

> I use GSP in Honors Geometry regularly. The students work through guided activities to reinforce or prep a lesson. The students enjoy it and we regularly reference the activities in lessons. In Pre-Calc and Algebra II, I use the calculators to assist in the teaching of graphing. We use it to develop graphs, intersections, intercepts, and tables. Students are generally lost on understanding graphing until we use the calculators. I use GSP in classes to demonstrate ideas visually that I can't really do by hand. For instance, I demonstrate the ambiguous cases for Law of Sines with GSP. It helps the students visually comprehend a concept. My Honors Geometry classes go to the lab twice a month to work through a guided activity. Sometimes it is a pre-lesson activity and

> sometimes it is a reinforcer. I use it as a visual illustration in other classes. GSP should be used to explore, reinforce and illustrate concepts (survey).

Beth integrated GSP into her Honors Geometry class through guided discovery labs she created. For example, in one lab she had students create two parallel lines cut by a transversal. After measuring all of the angles that are created, the students were prompted to make conjectures. Creating the labs herself indicated Beth's level of TCK. Putting the students into the position of forming conjectures using a guided discovery lab indicated a high level of TPK.

In a later lab on concurrency theorems (e.g. finding the in-center) Beth explained how the labs were also used for classroom discussion.

> And then the next day in class I told them to bring it back and then we pulled them out and we talked through them again so they had seen it and I don't have to draw it and represent it every time because they can print out what they did and look at it again. So, it makes the lesson go a lot better (lines 109-112).

When Beth was asked if she would use GSP with regular students she stated. "Oh, yea, oh yea absolutely. It's just such a good visual representation (line 314)."

Performance Tool

One interesting theme that emerged from John's and Beth's survey and interview data was the fact that each of them viewed GSP as both a pedagogical tool and a performance tool. As indicated above, John used GSP to create tests and worksheets. Beth was considered the expert in her school and was often sought out by other teachers to help them create different types of drawings. In the interview Beth described how she helped teachers create 30-60-90 triangles, isosceles triangles, and a pulley system on GSP. She stated that most of the teachers just didn't understand the transformation menu. "Actually my first year here I was doing an institute day, [we] took like an hour and a half and they had me show the other teachers how to use the basics of sketchpad. That was intimidating as a first year teacher (lines 150-152)."

Discussion

Results of the surveys and interviews with John and Beth revealed high levels of TPCK. One possible explanation could be that John and Beth were particularly strong in their undergraduate mathematics coursework, indicating the importance of content knowledge on TPCK.

Implications

As the instructor for Modern Geometry, my first goal was to use technology to impact student learning. When commenting about the class Mary remarked how using GSP helped her succeed in the course, "So [GSP] really helped, because I really struggled in that class. I was really good at Euclidean geometry but that hyperbolic geometry was really hard to visualize, because that is not how our lines work (lines 32-33)." John recalled:

> I just remember, for myself, comprehending it better because I could immediately see as many examples as I wanted to. All I had to do was change the location of a point and, you know, it would adjust the angles or whatever. I mean I could see, I could see a lot quicker and it was just more enjoyable for me to work with and I don't know. I think the class would have been kinda boring without it. But I thought it was really good (lines 116-121).

Beth had this to say. "Modern Geometry used GSP. I feel that it very much assisted in my understanding of non-Euclidean geometry. I also learned so much about GSP, I am considered the expert in my department (survey)."

The second technology goal for the course was to model an appropriate use of technology. When asked if Modern Geometry should be changed in any way all of the teachers stated that GSP should remain in the course. John summarized his sentiments as follows:

> Ah, so anytime you can teach, and you were the best at this, anytime you can teach while at the same time kind of integrating some pedagogy and different kind of instructional techniques other than lecture or drills. Lecture, you know that kind of thing. It helps us [future teachers] because that's my ultimate goal not just to learn high level mathematics but to learn how to teach math (lines 246-250).

Recall the research question "What evidence, if any, exists in the current teaching practice, of my former students, that indicates appropriate teaching with technology or TPCK?" Data collected from Lee and Mary indicated limited examples of TPCK. The data supported the conclusion that they both felt GSP was an important pedagogical tool for teaching high school geometry and both teachers discussed potential use in their future teaching. Data collected from John and Beth indicated a high level of TPCK with a variety of technological tools. The main difference between the teacher pairs, as undergraduates, was their success levels in mathematics content courses.

This study documented evidence of TPCK in the teaching practice of graduates of a technology intensive modern geometry course. Results suggest the level of TPCK attained by the teacher may be linked to their level of success in the course. Data for this study is self reported, which may cause an initial limitation. A further constraint is the prior relationship between the teachers and the author. The nature of the survey, as well as knowing the author's technology background, could have caused an expectation of technology use on the part of the teachers.

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