Intentional

For effective implementation in the classroom, this author uses technological, pedagogical, and content knowledge along with Pólya's four-step problem-solving approach.

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Teaching with Technology

In my fourteen years of teaching, I have often been given fancy technology to use in my classroom, and the hardware did nothing but sit around and collect dust. I feel guilty just thinking about it, but I know I am not the only teacher who has had this experience. Top-down implementation of technology is one of the most pervasive phenomena of the last couple of decades in educational history (Cuban 2001; Mishra and Koehler 2006). It is the subject of many books, articles, and blog posts on how to fix our schools or why educational technology is not working in the classroom (Cuban 2001; Mishra and Koehler 2006). The idea of providing teachers with technology so they can make our students ready for the real world or make learning an easier task is well intentioned, although, unfortunately, the time and money invested is often unproductive.

But poor implementation does not necessarily imply expensive mistakes. Well-intentioned lessons have led to extraneous uses of social media in the classroom. For instance, a teacher might have students talk about mathematical topics over Facebook® to encourage them to talk about math as they would any other subject in casual conversation; but it might be challenging for a teacher unfamiliar with that form of social media to predict how students would behave while logged on. Or imagine a teacher fluent with Facebook, but perhaps a novice teacher, who does not yet have control of his or her classroom. One can easily imagine how this plan might go wrong. Poor implementation results from a lack of understanding of some crucial component of how the technology supports learning the content, how the students will respond to the technology, and how well the teacher understands the benefits that the technology provides for his or her particular students.

Good implementation requires a deep understanding of context. Context includes both—

1. the broad learning environment (e.g., a moderately funded school run by a forward-thinking principal in a socio-economically diverse district); and
2. the more local, classroom-specific details:
   a. content;
   b. students;
   c. teacher;
   d. pedagogy;
   e. technology; and
   f. interactions among these components (Mishra and Koehler 2006).

The nature of effective technology use requires an understanding of—

1. the content;
2. students in their classrooms;
3. teaching the content to the students in their classrooms; and
4. the technology that teachers want to use for those students learning that content.

The name for the combined knowledge of these various domains is *technological*, *pedagogical*, and *content knowledge*, or TPACK (Mishra and Koehler 2006). Various combinations of these concepts exist, such as pedagogical knowledge that supports teaching content, which includes knowledge of particular common difficulties in learning content (PCK) (Schulman 1986), and knowledge of how technologies represent content in differing ways, depending on the technology used.

The TPACK framework is often responsible for successful implementation of technology to facilitate the learning of a particular concept taught by a particular teacher to particular students. Successful implementation of technologies that are already designed to treat a specific condition will work in settings they were designed for, as long as the teacher implementing them understands the technology (Mishra and Koehler 2006). That said, teachers are not necessarily inclined to implement something new to their repertoire that is not authentically their own idea (Cuban 2001). So, if teachers are inclined to avoid implementing existing, readily available, appropriate technology and are unwilling to comply with the current technological initiatives at their school, then how could they use TPACK to implement technology as a lesson-supporting structure?

Once the problem was reduced to a very specific relationship—student confidence in face-to-face, peer-to-peer discourse—seeing potential solutions to the problem became much easier.

A PROBLEM TO SOLVE

Teachers can adopt the TPACK framework to help ensure that their attempt to implement technology does not result in wasted time and confused students. Using this framework provides a scaffold for the necessary reflection on technology, pedagogy, content, and overall context required to assure that none of these components is taken for granted in the implementation of technology (Mishra and Koehler 2006). When I used the framework, I took an additional step and perceived technology implementation as any good mathematics teacher would—by turning my classroom into a problem to solve. In his book *How to Solve It* (1945), Pólya offers a straightforward framework for problem solving that consists of four simple steps: (1) recognize the problem, (2) devise a plan, (3) carry out the plan, and (4) look back. These steps offer a path to constructive reflection. In the remaining paragraphs, I will demonstrate how I used TPACK to address a contextual issue in my classroom through the lens of Pólya's framework.

RECOGNIZING THE PROBLEM

I began my problem-solving process five years ago when I noticed my students were struggling to use basic mathematical terms, such as *ratio*, *rectangle*, and *perpendicular*. I knew that they knew the meaning of the words, but they were insecure about using them. Whether it was because they were uncertain about exposing their mathematical ability or sharing their interest in mathematics with each other, or feeling the uncertainty that comes with attempting to speak in a foreign language in a foreign country, the problem distilled to social pressure. In my first solution, I implemented a flipped classroom that scaffolded content development within nightly problem sets. Solutions to problems were presented in class by students, which led to productive student-led discussion. Although this approach was quite helpful, students still demonstrated uncertainty in their use of mathematical language. I found them agreeing on partially true statements—the sort of statements one makes when one is still formulating ideas. For instance, I have heard students say, "The point is parallel to the line." Another student would say, "Yeah, totally," and then continue the conversation. Taken on its own, this scenario could be perceived as an instance of misspeaking. However, enough similar instances occurred that I concluded they were indicative of a problem. From my vantage point, I saw students' agreements as efforts to resolve awkwardness in moments when finding the right language to meet their intended meaning could have resulted in uncomfortable silences and visible struggle in front of each other. The discomfort of the social pressure overruled students' interest in letting a concept come to fruition.

I initially conjectured that discussing and discovering mathematics would give students enduring mathematical knowledge, but I also needed to construct a space that lifted the social pressure from their shoulders so they could speak more freely about mathematics. Thus, I discovered my problem.

DEVISING A PLAN

How I was going to "lift this pressure" in practice seemed impossible in a necessarily social environment. Not only does my class meet in a classroom at a school where students have established social bonds, but also the foundation of my classroom structure *is* social connection. Needless to say, I did not want to change the fact that students were communicating with one another—I wanted them to put their learning above the already-established social connections. Anyone who knows adolescent students knows this is a lofty goal, and I knew it, too. However, a substantial portion of communication is not face-to-face these days. Email, social media, texting, blogs—written communication in online venues—happens on a daily basis for every member of my classes, including myself. I came to realize that students talking online might be a way to lift that social pressure.

In essence, matching a form of technology to a pedagogical problem is the employment of TPACK, but doing this requires one to determine the aspect of the learning one wants to bolster. One can use technology to do things that are incredibly time-consuming to perform manually, such as make perfectly drawn, colorful histograms. Or one could use technology to understand Descartes' rule of signs by manipulating graphs and observing the changes in the polynomial expression, or vice versa. Solomon and Perkins

(2005) suggest that technology produces effects with, effects of, and effects through the experience of using it. *Effects with* is what we can do with technology to make elaborate histograms—the technology does some of the work for us so that we can focus on other aspects of the problem, such as data analysis. *Effects of* involves technology helping to produce lasting influences on the student's understanding even after the experience is over. For instance, the rule-of-signs example would represent this use of technology. *Effects through* implies a more substantial change in understanding. For instance, a teacher could develop dynamic geometry applets that potentially incite transformative effects

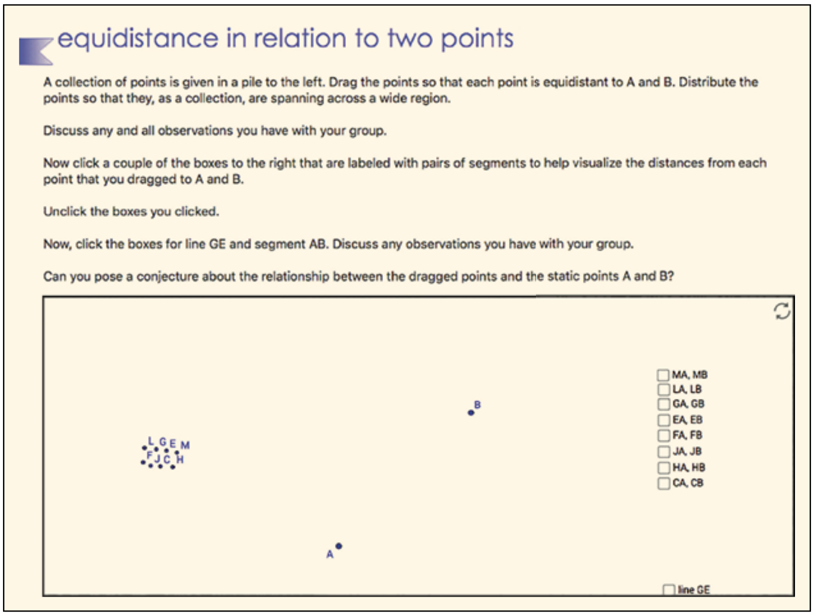

Fig. 1 This GeoGebra applet was designed to encourage students to discover perpendicular bisectors by employing the meaning of the word *equidistant*.

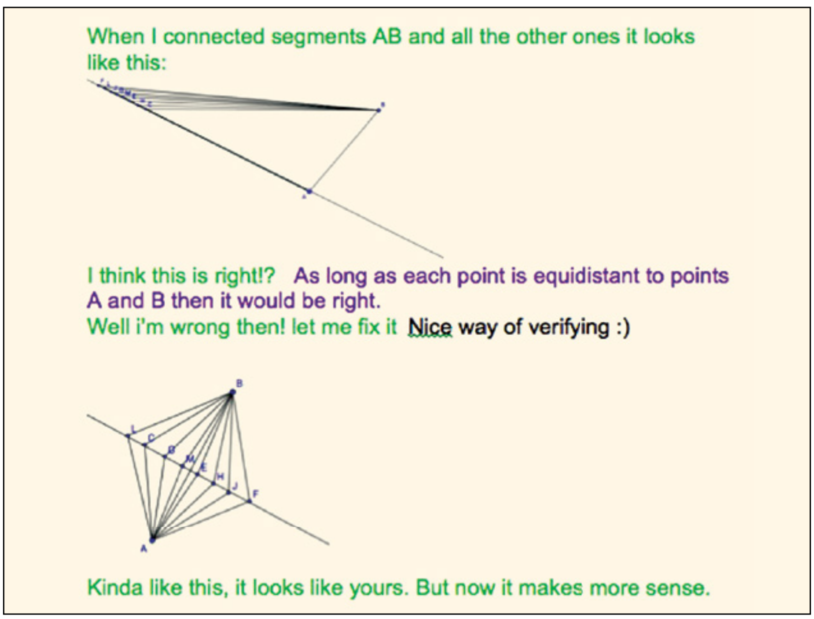

Fig. 2 Using Google Docs, students converse about the applet in **figure 1**.

on a student's understanding of triangles. Perhaps a student began playing with the applet thinking triangles are three sides and three angles. But later, she might understand that a triangle is a relationship among three noncollinear points. Technology provides different affordances for learning, and the key to solving a pedagogical problem with it lies in understanding the type of solution one wants.

I wanted students to experience enduring change in their ability to discuss mathematics, which led me to look for a technology that might potentially change their relationship with mathematical language—even after they were using the technology. I needed a technology that would relieve students of social pressure so they could freely talk about mathematics. My experience with technology was limited, which led me to one of the few things that I knew—the Google Docs™ online document application. Reflecting on my experiences in collaborating with colleagues at work in Google Docs—in meetings and asynchronously—led me to consider its potential as a medium in which students could converse. My personal experience communicating in writing versus face-to-face led me to consider the former as a viable way of potentially equalizing the social dynamics between students. I considered other platforms for talking through writing, such as blogging and messaging features in online forums; however, Google Docs offered additional affordances, such as the ability to drop images into the document in the precise space where the discussion is happening, which results in a show-and-tell within the discussion to support a continuous experience.

Once the problem was reduced to a very specific relationship—student confidence in face-to-face, peer-to-peer discourse—seeing potential solutions to the problem became much easier. Understanding that a piece of technology could resolve a pedagogical issue required an understanding of the technology itself and the context—the content, the students, and the teacher (myself). How was I going to include Google Doc discussions in class? Was I going to have the whole class log into one document and start talking? Some of the typical issues of class discussion might arise. For instance, some students might not communicate at all, whereas others might monopolize. I had to make sure that every student was contributing. I decided this activity would work best in small groups.

But what would activate discussion? I had to provide students with mathematical content that corresponded with the new mode of communication. Although I could have selected some applets on GeoGebratube.org, I decided to write some applets myself, so that the activity was authentic to my pedagogy. Developing learning tools with technology that not only corresponds to each component of the activity but also is in concert with the particular pedagogy of my particular classroom helped me invite such an atypical activity into our daily classroom routine.

This second element—the GeoGebra applet—filled out my approach to my initial problem. Students would do collaborative problem solving in small groups; the problem would be in a GeoGebra applet; and the discussion would be in a Google Doc.

CARRYING OUT THE PLAN

Implementing technology intentionally is more than simply executing a procedure. The TPACK framework requires an ongoing state of analysis of the context in relation to the intended technology. Thus, being responsive and improvisational are crucial to implementation. The key to successful implementation includes understanding the intended goal and being flexible enough to make responsive adjustments to meet that goal. My goal was to construct an environment where students could feel more comfortable expressing their mathematical thoughts in their mathematical language. I divided the class into groups of three students; each had a device. I sent each group a Google Doc and a link to the applet on geogebratube.org. Students settled in, distinguishing one person from another in their documents by claiming different colors with which to write, and they started interacting with the applet. I had each document open on my computer screen, and I was "present" in each one as an occasional contributor to each discussion. At first, students wanted to answer the questions in the applet individually, and they behaved as if they were distributing property—each student staked out different parts of the document as their own real estate and began writing their answers. Almost immediately, I needed to make an adjustment. Keeping my goal in mind, I told them to talk to one another, and I reminded them that this was meant to be a conversation not a test. After that, I spent my time bouncing among conversations, reading them and making sure that students did not go off tangentially. Brief statements sufficed to redirect them. Because the applet was focused on one concept, students were generally able to navigate the activity on their own.

The diagrams that follow demonstrate how students behaved in the activity. **Figure 1** is the GeoGebra applet (Mooney 2014) as it appears on geogebratube.org. **Figures 2**, **3**, and **4** are screenshots of a discussion between two students, one writing in green and the other writing in purple. My supporting feedback is in black.

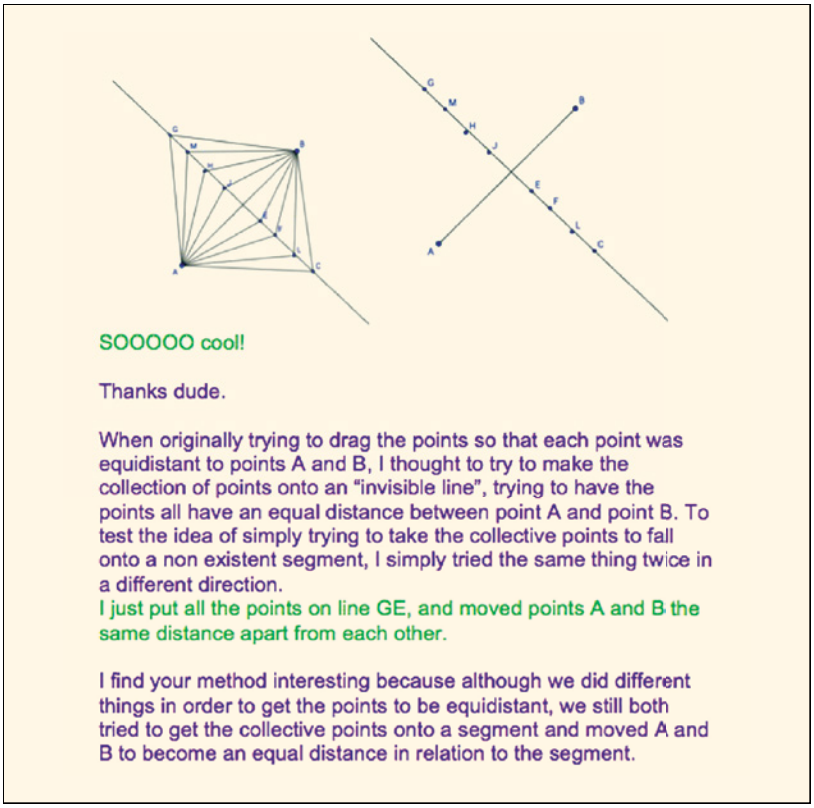

Fig. 3 The student conversation from **figure 2** continues.

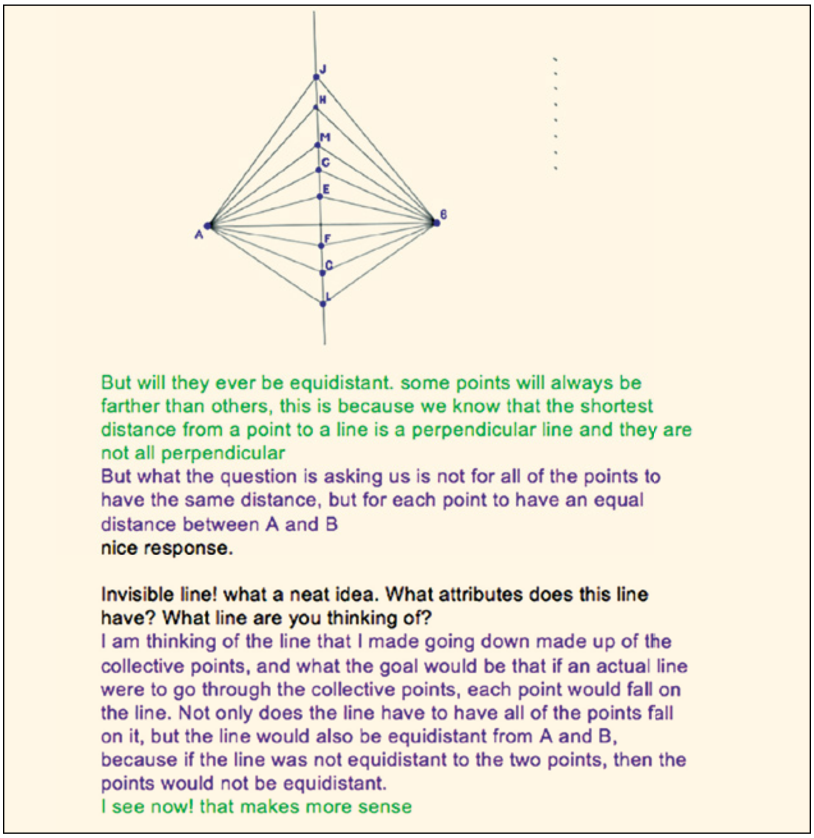

Fig. 4 The student conversation from **figure 3** continues.

LOOKING BACK

Looking back requires one to consider the problem, the solution, and whether the solution addressed the problem (Pólya 1945). In other words, did the chosen technology address the problem? I restated the problem: Students were reluctant to use mathematical terms in the presence of their peers. I summarized my solution, which was divided into two parts, the plan and the results. The plan was to have students communicate with one another in a synchronous, online format—a Google Doc and GeoGebra applets. The results revealed students discussing mathematical concepts with their mathematical vocabulary. When I read the dialogue later, I had the following thoughts.

The student who wrote in purple was an artist and a visual thinker. She was typically an observer, rather than a frequent contributor to discussion. In this activity, though, she became the resident expert. Communicating through writing and through GeoGebra gave her an opportunity to interact with abstract concepts in a tangible way and articulate quietly with her written language.

What else happened? What in-activity adjustments must I make? I must be responsive and change the directions so that students speak to each other rather than answer the questions in

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separate parts of the document. To make sure that the technology satisfies its intended goal, I must be as engaged in the activity as my students are engaged.

So, *was* the Google Doc an effective technology? Was the GeoGebra applet effective? Yes, they provided the intended experience and created more opportunity for students to speak mathematically in a low-pressure setting. Finding ways to use technology in meaningful and intentional ways is an iterative process that requires observation, responsiveness, a sense of adventure, focus, and reflection.

A NEW PATH TO LEARNING

My intimate understanding of the problem in my classroom resulted in finding an inventive way of using common technology that I could not have expected even a keen observer to think of. I understood both the broad and the local components of my context. I understood the content, my students, and what I wanted for my students—and with that, I chose technologies that had the potential to resolve the conflict in that context. With technological, pedagogical, and content knowledge, I discovered a new avenue for learning mathematics, and through this, my students might also have been given an opportunity to see themselves in a new light—as mathematical thinkers.

REFERENCES

Cuban, Larry. 2001. “Oversold and Underused: Computers in the Classroom.” Cambridge, MA: Harvard University Press.

Mishra, Punya, and Koehler, Matthew. J. 2006. “Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge.” *Teachers College Record* 108, no. 6 (June): 1017–54.

Mooney, Eileen B. 2014. “Explorations in Euclidean Geometry: 1. Building Relationships between Points: 6. Equidistance in Relation to Two Points.” *GeoGebra.org*. https://www.geogebra.org/m/rrycz5AD#material/thkbw3G6

Pólya, George. 1945. *How to Solve It: a New Aspect of Mathematical Method*. Princeton, NJ: Princeton University Press.

Salomon, Gavriel and Perkins, David. 2005. “Do Technologies Make Us Smarter? Intellectual Amplification with, of, and through Technology.” In *Intelligence and Technology: The Impact of Tools on the Nature and Development of Human Abilities.* Edited by Robert J. Sternberg and David D. Preiss, pp. 71–86. Mahwah, NJ: Lawrence Erlbaum Associates.

Shulman, Lee S. 1986. “Those Who Understand: Knowledge Growth in Teaching.” *Educational Researcher* 15, no. 2 (February): 4–14.

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We will also Storify the conversation for those who cannot join us live.

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