

Teacher Self-Efficacy in 1:1 iPad Integration in Middle School Science and Math Classrooms

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Abstract

Many schools are beginning to adopt one-to-one computing with the goal of developing students' 21st-century skills, which allow students not only to learn content but to acquire critical skills (e.g., creativity, collaboration, and digital literacy) that will lead to future careers. Technology offers teachers the ability to transform the quality of instruction—to achieve a more student-centered learning environment, have more differentiated instruction, and develop problem- or project-based learning, and demand higher order thinking skills. A number of barriers and influences have emerged from the findings of this study on teachers' practice and integration of technology into their classrooms. This study examines how these barriers, both internal and external, influence classroom pedagogy. Using a technology, pedagogy, and content knowledge (TPACK) framework, this paper examines the classroom practice of two middle grades mathematics and science teachers integrating a 1:1 initiative and the ways they dealt with the barriers in their classroom practices.

Teacher Self-Efficacy in 1:1 Tablet Integration

Many schools are beginning to adopt 1:1 computing with the goal of developing students' 21st-century skills, which allow students not only to learn content but to acquire critical skills (e.g., creativity, collaboration, and digital literacy) that will lead to future careers (Pellegrino & Hilton, 2012). *The Next Generation Science Standards* (Achieve, 2013) emphasized the relationship between science, engineering, and technology and the application of such ideas that allow scientists and engineers to “develop or improve technologies, often [raising] new questions for scientists' investigations” (National Research Council, 2012, p. 203).

Technology offers teachers the ability to transform the quality of instruction—to achieve a more student-centered learning environment, have more differentiated instruction, and develop problem- or project-based learning, and demand higher order thinking skills (Penuel, 2006). Additionally, mobile 1:1 technology in the classroom offers many benefits to student learning. According to Lipponen (2002), technology can enhance peer interaction and group work, facilitate knowledge sharing, and distribute knowledge and expertise among the learning community. By having technology used on a daily basis in the classroom, teachers are improving their practice as well as their students' learning and knowledge advancement.

Researchers have demonstrated that technology integration is essential to meet this goal (e.g., Keengwe, Schnellert, & Mills, 2012); however, existing technology infrastructures are often insufficient to develop the desired outcomes of these implementations (Greaves, Hayes, Wilson, Gielniak, & Peterson, 2012). Many current classroom teachers have yet to incorporate technology into their teaching practices. Teachers often do not understand or have the time to spend learning about the functionality of the devices.

According to Ifenthaler and Schweinbenz (2013), a majority of teachers are open to integrating tablets and feel they would enhance their practice, but others are not confident about using a new device in their everyday instruction. In addition, the ways teachers integrate devices into their practice is often dictated by school culture (Fleisher, 2012; Greaves et al., 2012). Others have shown that internal barriers, attitudes, beliefs, and self-efficacy with technology still impact levels of technology integration (e.g. Kim, Kim, Lee, Spector, & DeMeester, 2013). With the United States government distributing *Race to the Top* funds for 1:1 mobile initiatives, developing a protocol for successful implementation of technology would benefit schools, teachers, and students.

Using a technology, pedagogy, and content knowledge (TPACK) framework (Mishra & Koehler, 2006), this research project examined the classroom practice of two middle grades mathematics and science teachers integrating a 1:1 initiative. The following questions guided our research:

- What types of external and internal barriers exist within the classroom and school environments that influence technology use and integration by these teachers?
- How do internal influences affect these teachers' perceptions of their own pedagogical practices integrating technology?

Background Literature

Currently, little research has examined teacher appropriation of tablets into pedagogical practices (e.g., Fleisher, 2012; Greaves et al., 2012). Many teachers are resistant or not sure of how to integrate technology into their everyday teaching (Greaves et al., 2012).

Teachers are an integral part of integrating technology into K-12 classrooms. When technology is used regularly in the classroom, teachers' practices, as well as students' learning, improve (Kim et al., 2013). Classroom technology is integrated into content and pedagogical practices at the teacher's discretion; not all teachers will integrate technology into their practice, and those who do use technology adopt the technology in varying degrees of integration. Typically, teachers who have more student-centered pedagogical beliefs will integrate technology as a part of their classroom, whereas teachers who have

more teacher-centered beliefs are more likely to use technology as an enrichment activity (Kim et al., 2013).

Barriers, both internal and external, exist for teachers integrating technology. An external barrier can be described as institutional resources, such as having access to available technology, time with technology, technical support, and the technical infrastructure to adequately support technology integration (Hew & Brush, 2007). Internal barriers include attitudes, beliefs, and self-efficacy with technology, which all impact teacher technology integration (Kim et al., 2013). Specifically, one barrier that prohibits teachers from integrating technology into their practice is teachers' own beliefs and comfort levels with technology.

In an early study by Ertmer (1999), barriers were categorized as first and second order barriers. Teachers cited first order or external barriers, such as a lack of computers, computer software, and limited access to the Internet as reasons why they did not use technology in the classroom. Second order, or internal, barriers were not as frequently cited as the main barrier for technology integration.

When Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, and Sendurur (2012) revisited the original study 10 years later, this trend had reversed. They found that a majority of teachers listed internal barriers, such as teacher attitudes and beliefs, as the main reason for lack of technology integration. When teachers were "asked to name the biggest barrier, overall, to technology integration in their schools...[a majority] described other teachers' internal barriers" (p. 433). Other internal barriers identified in the prevention of technology integration were teachers' confidence with technology, beliefs about how students learn with technology, and teachers' perceived value of technology in the classroom. In a 1:1 initiative school many of these first order, or external barriers, are no longer a predominant issue; however, teachers' second order, or internal, barriers still inhibit technology integration.

Professional development (PD) support in using technology could be an important factor for successful implementation by teachers in their classrooms. The different types of technology available for classroom use pose a variety of problems for teachers, yet, at the same time offer many unique teaching opportunities. Kim et al. (2013) demonstrated that when teachers had access to technologies, workshops, and technical and pedagogical assistance, the levels of technology integration were not the same. Instead, teachers' pedagogical beliefs played a larger role. The teachers who had more student-centered pedagogical beliefs were better at integrating technology as a part of their classroom, whereas those who had teacher-directed pedagogical beliefs were more likely to use technology as enrichment to the lesson (Kim et al., 2013).

Additionally, when teachers lack the knowledge of how to use technology, their attempts to integrate it successfully are often limited (Koehler et al., 2014). This study built on previous work by Vannatta and Fordham (2004) who found three factors that best predicted how a teacher integrated technology: time commitment, willingness to change, and amount of technology training.

When examining technology integration in science specifically, Guzey and Roehrig (2009) found similar results to Kim et al. (2013). Guzey and Roehrig observed four beginning secondary science teachers' technology integration over the course of one school year after the teachers had attended a summer PD focused on technology integration in secondary science. They found that two of the teachers who had prior experience with technology described themselves as "technology enthusiasts" and were more comfortable with technology overall and looked for more opportunities to improve

their technology integration into their science instruction. These two teachers also exhibited a more student-centered pedagogical style than did the two teachers who struggled to integrate technology into their classroom instruction.

Two areas of research that have not been fully examined are teacher self-efficacy—teachers’ beliefs about their classroom practice (Paraskeva, Bouta, & Papagianni, 2006)—and teacher computer self-efficacy—teachers’ beliefs about their ability to use technology in the classroom (Mueller, Wood, Willoughby, Ross, & Specht, 2008). Previous research primarily examined teacher self-efficacy and computer self-efficacy with general technology in the classroom. This study will begin to examine a science and mathematics teacher’s self-efficacy in a 1:1 mobile school and the influence of professional development situated in the classroom on that self-efficacy. Qualitatively, this research will examine how a teacher’s perceived classroom technology education differs, if at all, from the observed integration of technology.

Teacher technology self-efficacy is a difficult topic to measure using traditional experimental designs. Most of the quantitative research for studying teacher self-efficacy consistently has used descriptive research to help define the phenomenon that is happening. The studies use a sample at one point in time to determine teacher self-efficacy with technology in the classroom and use a self-report survey (Hermans, Tondeur, van Braak, & Valcke, 2008; Holden & Rada, 2011; Hsu, 2010; Kumar, Rose, & D’Silva, 2008; Mueller et al., 2008; Paraskeva et al., 2006; Teo, 2014; Vannatta & Fordham, 2004; Wozney, Venkatesh, & Abrami, 2006).

Using a single-time questionnaire to gather data about self-efficacy has both positive contributions and limitations. Results from analyzing questionnaire data are easily generalizable to other populations because of the potentially large number of participants in the studies. Using a questionnaire is also a way to determine a general consensus of a large group of individuals. A limitation of the single point sample survey method is that the questionnaires are comprised of self-report data. The data collected are representative of the participants’ views of their technology use in the classroom at that particular point in time. Each participant may have a different understanding of technology integration and, thus, respond to the questionnaire differently because of the differing viewpoints. This circumstance could affect the validity of the study through statistical regression, by creating extreme scores on the instrument and through personal variables generated by the individuals in the study. The quality of the self-report questionnaire also impacts the validity of these studies.

In a further examination of the literature, a few studies employed single-group experimental designs. Abbitt (2011) used a single group, pre-posttest design to evaluate the relationship between teacher self-efficacy beliefs toward technology integration and the teachers’ perceived knowledge in the technological pedagogical content knowledge (also referred to as technology, pedagogy, and content knowledge, or TPACK) domains. In another study, Kopcha (2012) employed the same design to determine the effects of situated professional development on teachers’ technology integration in the classroom. Both studies had the participants complete a pre- and postquestionnaire.

Abbitt’s (2011) participants took a 16-week course on integrating technology in the classroom. This study was beneficial because it examined the effect of the 16-week long technology course on the participants’ knowledge and self-efficacy with technology. One impediment to the study’s usefulness was that the study gathered information only about the participants’ perceptions of knowledge of TPACK domains and self-efficacy beliefs. No evidence of demonstrated knowledge of ability with technology was found.

Kopcha's (2012) treatment was the implementation of situated PD provided by the researcher. Situated PD is when teachers are active learners, constructing their own knowledge, and the PD takes place in classroom practice (Swan et al., 2002). The study used qualitative methods as well as quantitative methods to collect data. The researcher conducted classroom observations of teachers using technology and one-on-one interviews to support the data collected via the questionnaires.

Research focusing on science teachers' self-efficacy with technology is limited in scope. Graham et al. (2009) studied teacher TPACK confidence prior to and after a professional development that focused on science subject-specific pedagogy and biology/earth science content knowledge. Graham et al. (2009) used a pre-and postquestionnaire related to the four TPACK constructs that involve technology to examine science teachers' confidence with TPACK. The study found that the highest confidence was in participants' technology knowledge, which supports the authors' notion that technology knowledge is foundational to developing confidence in the other three forms of technology knowledge (i.e., technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge). The participants' lowest confidence was technology content knowledge, which could be because technology content knowledge is most closely linked with doing science as opposed to teaching science. Educators were more confident in their ability to use technology to teach science (e.g., word processing, PowerPoint presentations, and Internet research) than they were in their ability to use technologies that are designed to do science (e.g., digital probes and digital microscopes).

Teacher self-efficacy has been studied through qualitative research methods, mainly through case studies, cross-examining the case studies, and meta-ethnography. Researchers collect their data for case studies in a few ways. One method is through interviews and classroom observations over an extended period of time (Ertmer et al., 2012; Kim et al., 2013) and by using a specific observation protocol (Looi, Sun, Seow, Chia, 2014).

Some studies use the case study method when they are examining teacher beliefs and technology integration, teacher perception of technology integration, and teachers' journeys when using new technology in the classroom (Ertmer et al., 2012; Looi et al., 2014). Ertmer et al. (2012) developed cases by examining teachers' class websites using in-depth document analysis and conducting one-on-one interviews with the teachers.

Looi et al. (2014) developed cases on four teachers implementing a 5E-Technology-oriented science curriculum. The 5E-Technology model is a five-step model in developing lesson plans. The 5Es are engage, explore, explain, elaborate, and evaluate. The cases analyzed how the four teachers used the same curriculum and PD in different ways. Looi and colleagues used classroom observations as their case data. With each observation field notes, observation sheets, and video and audio data were collected.

Cross-comparing case studies allows for researchers to gather data about individuals and find common and contrasting themes from the data. Hughes (2005) used cross-comparison case studies when she examined four English language arts teachers and how they used technology to support their practice. The four teachers had varying years of experience and were interviewed on three different occasions. Three technology-centered lessons were also observed to create each individual case. Each case was presented and then crossed with the other cases to display common themes and trends.

This method is beneficial because it dives deeper into teachers' perceptions and thinking. By using both interviews and observational data the researcher is able to

compare teachers' perception of their practice to teachers' actual classroom practice with technology. The limitation of case studies is that the teachers are not given a voice. There are no direct quotes from the teachers who participated in the study, which lowers the authenticity of the study. Hughes (2005) did, however, provide thorough descriptions of the English language arts teachers' technology use and how they compared to one another.

Another example is found in the study by Tondeur et al. (2012). The researchers use a meta-ethnography to synthesize qualitative data from multiple studies focusing on technology training for preservice teachers to make new interpretations of the data. Existing qualitative studies were examined to find common themes among the literature. These themes were then synthesized to create a model for teacher education programs to prepare preservice teachers to use technology in their future classrooms. The study's aim was to inform the technology education programs already in existence and influence their methods of preservice teachers' future technology integration.

The study described in this paper attempted to utilize the current research to advance the knowledge about teacher technology self-efficacy. It adds to the literature about ways teachers use mobile 1:1 technology in the classroom and the ways specific PD increases teacher technology self-efficacy.

Theoretical and Methodological Frameworks

Design-Based Research

This study is part of a larger design-based research project (Brown, 1992) that is examining the use of iPads within specific content contexts. Design-based research emerged from the dialectic between theory and design in research, with theory suggesting an improved design and design suggesting new dimensions to theory. While theory and design can and do exist independent of one another, an inherent connection still exists between them. Design-based research is an iterative process that is based upon outcomes that can impact the modification of instructional practice through monitoring and self-regulation (Schoenfeld, 2006).

According to Brown (1992), the goals of design experiments are important educational goals. Students and teachers in these classrooms function as researchers, teachers, and monitors of their own progress. With the help of technology, they are able to facilitate learning, collaboration, and reflection. As a result, these experiments are able to produce data that enables those who are involved to draw warranted conclusions about student learning and what contributes to it.

Scardamalia and Bereiter (1991, 1994) demonstrated in numerous studies that when instruction included the students' collective responsibility for knowledge generation and content understanding, students felt empowered to take ownership in the discovery and refinement of information. This knowledge building includes ways in which the classroom environment is designed to focus on

real ideas, authentic problems; improvable ideas; idea diversity; working toward more inclusive principles and higher-level formulations of problems; epistemic agency; community knowledge and collective responsibility; democratizing knowledge; symmetric knowledge advancement; pervasive knowledge building; constructive uses of

authoritative sources; knowledge building discourse, and embedded and transformative assessment. (Scardamalia, 2002, p. 75)

TPACK

TPACK is the framework utilized in this study that describes the knowledge required to integrate technology into the classroom (see Figure 1; Mishra & Koehler, 2006). This framework describes teacher knowledge of all three domains—content, pedagogy, and technology—and how it can be drawn upon in a synergistic manner. The framework builds upon the earlier work of Schulman's (1986) pedagogical content knowledge (PCK) that describes how teachers must draw upon their knowledge of course content and pedagogical approaches.

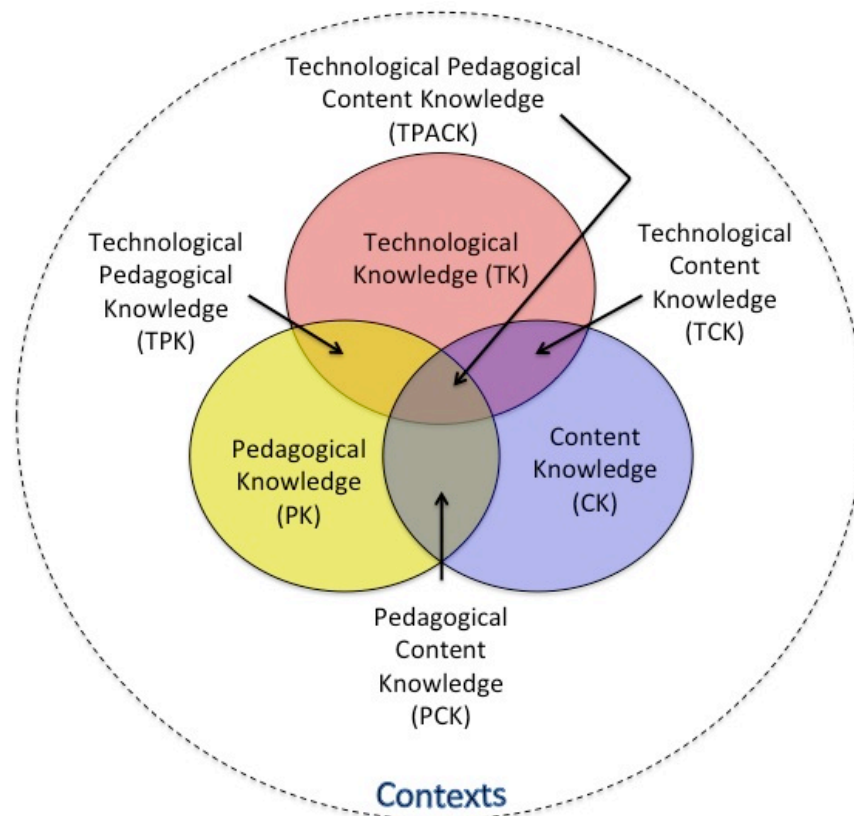


Figure 1. *TPACK, or technological pedagogical content knowledge (Mishra & Koehler, 2006).*

Previously, PD around technology has focused on introducing the affordances of the technology with the assumption that teachers could connect these to their teaching practice (Kopcha, 2012; Matzen & Edmunds, 2007). TPACK provides the framework to organize teaching with technology, allowing teachers to bring together content, pedagogy and technology. Educators' TPACK, or technology integration knowledge, is operationalized when they identify an effective combination of curriculum content, a particular pedagogical approach, and a use of a technology tool or resource to support the learning experience.

Focusing on scientific content, Jimoyiannis (2010) developed the technological pedagogical science knowledge (TPASK) framework based on the TPACK framework. The TPASK framework focuses not only on the technological aspects but includes integration of pedagogical and instructional issues of educators. Jimoyiannis noted that having TPASK means more than just being a content specialist or a technology specialist; it means that science educators have knowledge of all components and how to utilize them in their classrooms. Guzey and Roehrig (2009) and McCrory (2008) supported this notion in their research and emphasized the importance of in-depth knowledge of scientific concepts, as well as the dynamic development of pedagogy and technology knowledge.

Research Design and Methodology

Study Context: School and Students

Caldwell Middle School is an urban middle school in the southeastern portion of the United States. (Pseudonyms are used for schools, teachers, and students.) It is a Title I school with a diverse population ($N = 647$). The demographic profile of the school at the time of this study consisted of the following: White, 8%; African American/Black, 66%; Asian, 3%; Hispanic, 21%; Native American, 2%; and Multiracial, 2%. Eighty-percent of the students receive free or reduced lunch, with 81% being classified as economically disadvantaged, 11% with limited English proficiency, and 19% with disabilities. The school was purposively selected based on its implementation of a 1:1 iPad initiative funded through the federal Race to the Top to address technology integration in the classroom.

Study Context: Teachers and Classrooms

A larger study focused on a sixth-grade team (students, $n = 100$; teachers, $n = 4$) of teachers across the content areas. Teachers were purposively selected with the assistance of the principal of the building. After the University Institutional Review Board and the District Research Office approved the study design and the proposal, teachers were invited to participate. All members of the sixth-grade team agreed to participate and returned the consent forms.

For this paper, two members of this team are the focus, Jake and Isabell, due to their content areas of science and math. Jake and Isabell were both classified as highly qualified teachers with masters degrees. Both were White, had 5+ years of teaching experience, and were traditional in their instructional approaches, relying primarily on didactic instruction such as lectures and worksheets. Some demonstrations were presented, but students were not active participants in these activities. Both teachers appeared to have well equipped classrooms with lab equipment for inquiry.

The participants were reflective of the larger teacher population at Caldwell and of the district, predominantly White, in contrast to the student population, which was predominately African American/Black. When breaking down the teacher demographics of the school, the following information was determined. Twenty-two percent of the teachers were male and 77% were female. A large portion of the faculty was White (63%). The remaining 37% of the faculty was broken down as follows: African American/Black, 34%; Hispanic, 2%; Native American, 0%; and Other, 0%. Ninety-four percent of the teachers at Caldwell met the federal guidelines for highly qualified, with 39%, including Jake and Isabell, having advanced degrees.

Data Sources

Multiple sources of data collection are part of this study, including semistructured interviews with teachers, circle of influence diagrams (see [Appendix](#)), field notes and observations, teacher lesson plans, and video data. These multiple sources allowed for the triangulation of the data. The data collected documents teachers' perceptions and uses of technology, mainly the iPad, in their pedagogy. We examined interview transcripts, field notes, and lesson plans and evaluated the data using a constant comparative method (Corbin & Strauss, 2008). Data collection and analysis was an iterative and inductive process. Data was organized into core categories (Corbin & Strauss, 2008), which provided a framework for observing and analyzing teachers self-efficacy and use of technology in their classroom.

Teacher reasoning was captured through the interviews. As part of these interviews, teachers participated in the construction of a circle of influence diagram. In this diagram, the teachers talked through the influence of different types of technologies on their instructional practice. Using Inspiration software, they moved these technologies toward or away from their circle of instructional practice, indicating the type of influence a specific technology had on their practice. Through a think-aloud protocol, additional insight was given to the reasons for the placement of the technology. This data supported and refuted the emerging hypothesis about teachers' self-efficacy and use of technology in their classroom practice.

Data Analysis

Interview data were transcribed and analyzed using HyperTranscribe and HyperResearch. Members of the research team, including faculty researchers and doctoral students, independently reviewed data from the larger study ($N = 8$ Grade 6 teachers) and coded the responses using a grounded theory, constant comparative method (Corbin & Strauss, 2008). We developed an initial set of codes that emerged from this open coding.

In this second iteration, we looked for codes that were present in the interviews but absent from the draft code sheet. Coding results were compared and formal descriptions were developed for each code that had a high level of agreement (see Table 1). Discrepancies were discussed and the reasons that they occurred were identified. Once definitions were decided, a third set of interviews was coded and an interrater reliability of $r = 0.95$, was established. Cohen's kappa was calculated to show that $\kappa = 0.84$, which indicates that the frequency with which raters agreed is stronger than by chance alone. Once final coding schemes were established, the remaining interviews and field notes were analyzed. Data were triangulated across interviews, field notes, lesson plans, and classroom observations in order to increase trustworthiness and validate the findings of this study (as recommended by Lincoln & Guba, 1985).

Once data coding was completed, we reviewed the coded data and further grouped the codes by relating code categories and properties to each other using both causal and generic relationships. This practice allowed for the synthesis of individual codes into larger, overarching themes. Developing these themes by adding and moving codes was a reciprocal and iterative process. We used these themes to organize and summarize the data through narrative. We discuss these themes and provide examples of evidence in the section that follows.

Table 1
Codes and Definitions

Code	Subcodes	Definitions
Theme: External Barrier		
Institutional	Apps on iPads	All iPads, regardless of grade level, have the exact same apps on their iPads – no regard to curricular differentiation.
	Lock down	Students and teachers have no administrative access on iPads – includes allowing for download of app and access to websites
	Restriction on Location	Students cannot take iPads home to do school work
	Professional Development	Lack of appropriate PD – teachers wanting to have more PD that is useful to their practice
	Institutional Logistics	Organization for distribution of iPads to students including the beginning of the day and end of day collection.
Infrastructure	Connectivity	Building Internet access
	Apps Acquisition	Process for getting new apps on the iPads that connect to specific class topics
	Infrastructure Logistics	Homeroom teachers are responsible for students getting iPads
	Software updates	Timely process for ensuring all software is updated
Theme: Internal Barriers		
Personal Decisions		Curricular and pedagogical decisions made about using the iPad in instruction
Time		Lack of time for integration
Technology Knowledge		General knowledge about technology and how to integrate technology into pedagogical practices
Theme: Perceptions		
Positive of Self	Sees self using the technology	Has a positive outlook on their own technology use
	Sees self as an expert	Views self as an expert with technology
	Sees how technology relates to relevant content	Has a positive view of how technology improves their content area instruction
Negative of Self	Does not see self using technology	Has a negative outlook on their own technology use
	Does not see self as an expert	Does not view self as an expert with technology
	Does not see how technology relates to relevant content	Does not view technology as being relevant or helpful in their content area instruction
Positive of Others	Sees others using the technology	Has a positive view of other teachers technology use
	Sees others as experts	Recognizes others as being experts with technology
	Sees how technology relates to others relevant content	Acknowledges that technology is relevant and helpful in other content areas
Negative of Others	Does not see others using technology	Has a negative view of other teachers technology use

Use of Technology	Does not see others as experts	Does not recognize others as being experts with technology
	Does not see how technology fits into other content areas	Does not acknowledge that technology is relevant and helpful in other content areas
	Actual Use	Teachers actual and observed technology use in the classroom
	Perceived Use	Teacher's perceived use of technology in the classroom

Results and Discussion

A number of barriers and influences emerged from the findings of this study on teachers' practice and integration of technology into their classrooms. Ertmer (1999) described both external and internal barriers that plagued teachers as they attempted to integrate technology into the classroom. The external barriers focused mainly on infrastructure and institutional barriers that are in place and whose intention it is to help support and structure the technology use, though they tended to create more frustration and confusion.

The internal barriers are those that are teacher induced and come from each individual teacher's own biases and experiences with technology. The two teachers in this study shared the same external barriers but presented their own unique individual barriers that prevented technology integration into their lessons.

External Barriers

Teachers face many external barriers to gaining knowledge of, access to, and use of technology. Though these barriers can be varied, they will experience some type of barrier (Ertmer, 1999). Ertmer also found that teachers do not list only one external barrier that prohibits their technology integration but rather a laundry list of concerns. The external or institutional barriers, such as connectivity issues, policies on software application acquisition, and professional development, are a few examples of external barriers that create a hindrance for teachers.

Connectivity. Having the school infrastructure established to handle the hundreds of iPads that need to be on the server at any given time is important. Students need to be able to access information quickly and seamlessly. If they are working on a project that requires access to the Internet but students are constantly inputting their credentials to gain access, they will not be able to complete the intended work. Isabell, the math teacher explained her frustration and why she did not work to integrate the iPads more frequently in her classroom instruction:

They'll get stuck at different parts. When I try to put [the document] up they have to reenter their credentials and this will go slow, and the Internet, you know, connectivity, and I'm like, "Oh this is so annoying." I think I am resistant to it because I had, you know, bad experiences when I do try to use it.

The constant inaccessibility appeared to lead to frustration of both Isabell and her students, resulting in a decline in technology use:

Do I feel like I've had a successful iPad experience? No, because even when I feel like it is a good lesson and it is gonna be good. Half of the kids don't get on, and I have to give it to them in a worksheet form. I don't have time to plan an iPad lesson and a backup lesson.

When Isabell had to plan for two lessons her focus was not on meaningful technology use that stimulates creative lesson design and student engagement but situated itself in teacher-directed worksheets. The lack of connectivity also limited the overall use of the iPad. A number of the apps that were being used required Internet access in order to run. Without this connection, *the apps were rendered useless*.

Professional development. PD needs to be structured to fit the technology needs of the teachers. Paraskeva et al. (2006) stated that teachers needed to overcome their resistance to technology by having PD that is specific to the teachers' content needs, while Mueller et al. (2008) found that focusing teacher technology learning within a classroom context improved teacher confidence and displayed technology as a potential instructional tool.

Caldwell Middle School had teachers participate in weekly technology PD. These PD sessions were usually comprised of multiple grade levels and content areas. The teachers were presented a skill for the week and, in some cases, they had to use it with their students before the next technology PD. The topics discussed were often varied and, according to the teachers in the study, they primarily focused on data mining and basic technology skills. Isabell stated multiple times that she would prefer to have PD tailored specifically to mathematics content. However, the majority of the PD sessions offered at the school were introductory episodes that focused on basic skills needed to navigate a website such as Google docs.

So [the PD sessions] are very basic most of the time, because we have all different levels of teachers with technology, in regards to technology. They are not always that useful for me because a lot of it is stuff you can figure out on your own, but I need them more about programs for math, things like that. They are not specific to content. For instance, at the beginning it was like, "Here is a Google doc. This is what you can do with it. Here is how you can use it for your kids to collaborate." Stuff like that, which is, like, if you've been using Gmail you've been doing this on your own the whole time.

Isabell had the most resistance among the teachers on the sixth-grade team to using technology in the classroom. She did not see the potential of using the iPad with math content or having PD that provided examples of how the iPad could potentially increase the iPad's value to her as an instructional tool. If the school had been engaging teachers in content-relevant technology PD, Isabell might have been able to begin to understand the affordances of integrating a tool such as the iPad. Without content-specific examples, however, teachers like Isabell will not see the benefits and, instead, will focus on traditional pedagogies.

Jake described their PD as being focused on data mining and other whole group initiatives:

We have PD all the time, a lot of data mining and whole group implementation for things like, for example, Reading Plus, which is an online reading program. But they also want you to be able to mine the data that comes off of it and analyze the data [for student] progress over time.

Although these uses of technology are important for tracking student progress on standardized curriculum, they do not improve how the teachers present the curriculum. Jake did not experience science content-specific technology PD, thus keeping the use of the iPads with respect to science inquiry at a minimum in his practice.

The skills that the current PD structure concentrated on did not generate a creative or innovative technology environment. Instead, it fostered the belief by teachers that technology is a separate piece of their lesson as opposed to an integral part of lesson construction, as suggested by the TPACK framework. Technology was viewed in isolation from pedagogical practices and content knowledge. In many instances, the students could have used pencil and paper to collaborate on their assignment instead of using the Google doc.

Jake also experienced frustration at the quality of PD that was offered at the school:

We have a surplus of technology and a lack of hands-on training. Because for you, for you to have 30 minutes of PD, it's not gonna cut it. You almost need a buddy system. It's like you said, a coaching model. You almost need a buddy system until you get your feet wet.

The teachers' individual needs were not being met through the PD, with both Isabell and Jake seeing little value in it. Both expressed a desire to continue PD but only if it was structured to fit their needs within their content-specific classrooms. Jake's and Isabell's desire to have content-specific PD is supported by research in science content and technology integration.

Jimoyiannis (2010), Niess (2005), and Guzey and Roehrig (2009) all found that teachers' confidence with technology integration with science content increased once the teachers had experience using the technology in content-specific ways. Additionally, based upon classroom observations, teachers' at Caldwell had different levels of technology knowledge within the school, suggesting the types of PD that they required would be different. The structure where only one skill is focused on and pedagogy and content are ignored is problematic.

Application acquisition. Policies and procedures existed within the institution and district for the process of getting apps downloaded to student iPads. These policies were another example of an external barrier that teachers had to overcome when using the technology in their classroom. The school policy stated that teachers must submit a request for an app to the Instructional Technology (IT) Department. If approved, the app would be downloaded to all of the iPads in the school. There was no curricular or grade level differentiation.

Both Jake and Isabell stated on several occasions that having everything exactly the same did not meet all teachers' and students' needs. While a few production and creativity apps could be used in all three grade levels, content apps should be varied and tailored to the specific content needs of the grade level. This would account for the technological content knowledge specific to each discipline (Mishra & Koehler, 2006).

Additionally, teachers had only administrative access on the teacher iPads, not the students. As a result, if teachers found an app they wished to use with their classes through their own preparation and exploration, they had to go through the acquisition process, which could often take up to several months. Because of this time-consuming process, teachers did not bother to ask for new apps to be downloaded to student iPads.

Frequently, by the time the download process had been completed, the teacher had moved on in the curriculum. Jake emphasized this frustration:

Applications that I have on my iPad that they [the students] don't have access to. Kids don't have it but we [teachers] have it, and so it is used for whole class instruction at that point. They [IT/Administration] do have the tendency to have the school on a lock step. They [IT/Administration] wouldn't want to download one app onto a set of tablets without doing it for the whole school.

This example described another external barrier where the IT Department/Administration imposed curricular decisions across grade levels, taking the pedagogical decisions away from the teachers. The barrier issue of control was a highly predominant theme throughout the study. Limits were set and student iPads were locked down, taking away the ability of the teacher to create lesson plans based upon ideas that emerged from their classrooms. By imposing these types of restrictions it changed the use of the iPads from a 1:1, potentially student-driven classroom to a whole class teacher-driven classroom with the teacher's iPad connected to a projector displaying the app, taking away from the purpose of a 1:1 initiative.

Another example of this problem emerged during an iterative learning cycle in the science classroom around the concept of sound waves, further illustrating the barriers associated with app acquisition. The following description is quoted from researcher field notes:

The science teacher became excited about the Decibel 10th app that was being used in the science lesson. The science teacher pulls the technology support administrator into the classroom to discuss getting the app put on student iPads for next year. The tech support administrator seems skeptical and reluctant to confirm that the Decibel 10th app could be downloaded. The instructional coach indicates that the app is free and the tech support administrator then notes that he does not like free apps because of the ads. The instructional coach assures the tech support administrator that there are no ads. The Tech support administrator then wants to know about in-app purchases. The instructional coach again confirms that it is completely free.

Jake was excited about the student-inquiry lesson that was presented in his classroom and wanted to obtain the app for future inquiry labs. The reluctance of the tech support administrator to support the teacher in his excitement for the app was an additional barrier to the teacher's technology use for lesson construction. It further perpetuated the denial of access to technology tools that teachers' wanted and needed to improve technology integration in their classrooms and contribute to student science learning. The denial of access prevented Jake from envisioning other inquiry labs with the iPads in his classroom. Jake continued to rely upon worksheets, concept maps, and demonstrations to present the science content, continuing the trend of passive student engagement.

Internal Barriers

Teachers may also have internal barriers that prevent them from utilizing technology in the classroom. Internal barriers come from teachers' personal experiences with technology, as well as their own biases, and teachers may not be aware that they exist (Ertmer, 1999). Internal barriers are much more personal, more deeply ingrained, and may require a pedagogical change in the individual over time in order to overcome them. These reasons make overcoming internal barriers much more difficult than the external

barriers previously discussed. These barriers can include, but are not limited to, teachers' own knowledge about technology, teachers' perception of their technology practice, and the value placed upon the technology itself.

Technology knowledge. Technology knowledge in this study is defined as what the teachers knew about technology available for classroom use. Technology ranges from the actual device to the various programs, apps, and websites that are available to support the device. Information is readily available; however, many teachers do not understand how to use the technology in classroom settings. In a study by Koehler et al. (2014), the researchers found that teachers' lack of technology knowledge often limited their attempts to integrate technology successfully. Both the science and the math teachers in this study cited several of these reasons to justify why they were not integrating iPads into their instruction. These reasons included not knowing what apps were available, the lack of time to learn these new apps, and the need for better PD.

Additionally, Jake and Isabell indicated through the course of their interviews that they were not aware of many of the different forms of technology present on the circle of influence (see Figures 2. and 3.) In these instances, these technologies had to be described to them. When further pressed, they also demonstrated a misconception of how these technologies could be used to improve their pedagogical practices and support the development of content knowledge, as shown by Jake:

- Jake: Ok, virtual worlds, would that be like a Sim simulation [that is, from The Sims Virtual World]?
- Interviewer: It could be a Sim simulation, it could also be something, have you ever heard of Quest Atlantis?
- Jake: Quest for Atlantis?
- Interviewer: No, Quest Atlantis
- Jake: Quest Atlantis, I've not heard of it.
- Interviewer: Of Whyville?
- Jake: I've heard of both of them, but I've not figured out how to incorporate them in the sciences yet. In regards to computer and video games, I would say that, um, I would say that I use that to some extent, we've used, um, we've used Destination Math or Destination Success.

Jake contradicted himself during the interview and demonstrated that he had little knowledge of how simulations and virtual worlds could be utilized in the science classroom. Two virtual worlds, Quest Atlantis and Whyville, were mentioned that have science components embedded in them. For example, in Quest Atlantis-Taiga, students investigate a fish kill in the river system, analyzing water samples and making observations and predictions about the surrounding environments (e.g., Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005; Barab et al., 2007); however, due to Jake's limited knowledge about this available technology, he stated that he had "not figured out how to incorporate them in the sciences yet." With a better understanding of the affordances of these technologies, he might be able to recognize that he did not have to incorporate the worlds but, instead, work to decide which parts of these worlds fit the needs of his classroom and students. Jake also mentioned Destination Math and Destination Success, which are math and reading curricular programs that are not simulations or virtual worlds. These two programs were, in fact, not related to science curriculum at all.



Figure 2. Circle of influence on science teaching practice – Jake. (Click on image for a larger version.)

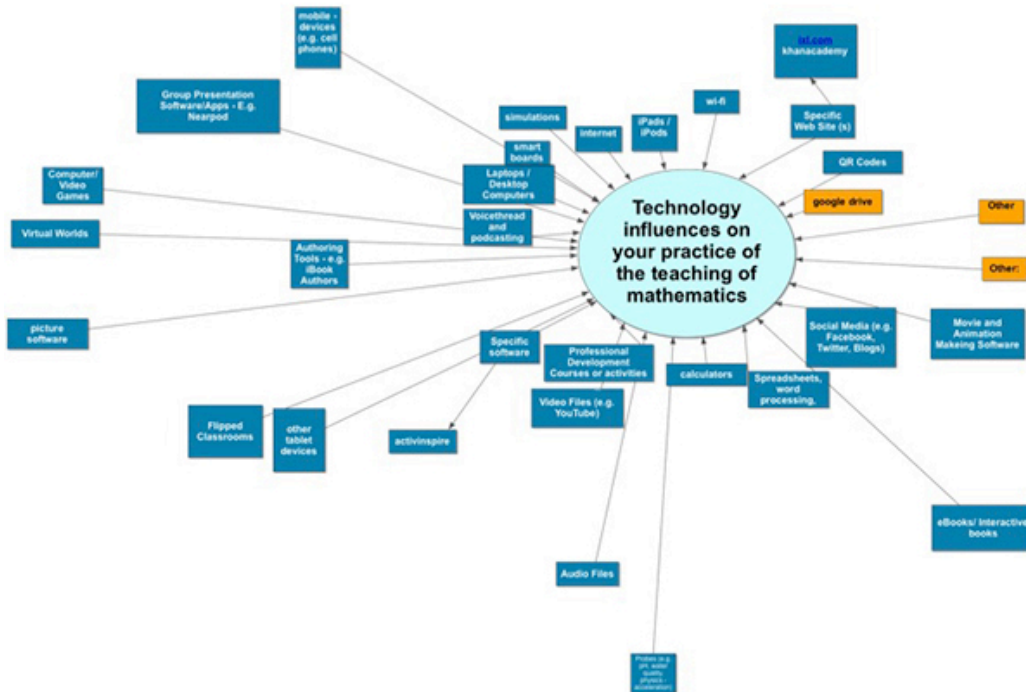


Figure 3. Circle of influence on mathematics teaching practice – Isabell (Click on image for a larger version.)

Jake's limited knowledge was echoed in his comments about PD. He stated on numerous occasions, "We have a surplus of technology and a lack of hands-on training." This point is key in successful technology integration. Previous studies have suggested that teacher PD needs to be technology and content specific (Mueller et al., 2008; Paraskeva et al.,

2006), and hands on (Judson, 2006; Paraskeva et al., 2006) and must promote positive interaction with the technology (Kim et al., 2013; Mueller et al., 2008; Vannatta & Fordham, 2004). Clearly, from his interview and observations this kind of PD was not occurring at Caldwell.

However, with the research team Jake did experience several examples of how to integrate technology with science content. The first model lesson was an inquiry focused Sound Inventory, where students used their iPads (e.g., Decibel 10th app) to collect and analyze sound data from around their school. The lesson was implemented by the research team and was structured such that students developed argumentation about sound levels in the school.

The second iterative learning cycle involved inquiry lessons on plate boundaries, movement, and the resulting physical land features. For this learning cycle Jake and the researchers planned the lesson together, giving Jake more opportunity to become familiar with different ways to create an inquiry lesson utilizing the iPads. Jake chose the app Puzzling Plate Tectonics to be the main component of the inquiry lesson. The app provided multiple modalities in presenting information about plate boundaries, movement, and the resulting physical land features.

Due to the design of the app, students could work at their own pace in partners. They were given initial instructions and had a handout that helped guide them through the different phases of the app. In this cycle, we modeled the inquiry for two of the classes, with Jake implementing the lessons in the rest of the classes. These two experiences were situated in Jake's classroom, and he was involved in the planning and implementing of the technology-infused science inquiry lesson. These offer two examples of the type of models that teachers can benefit from in increasing their technology knowledge with respect to content.

Likewise, Isabell exhibited limited technology knowledge similar to Jake, but with respect to available math simulations and manipulatives, as was demonstrated in this conversation:

Simulations. Tell me what you mean by that....So if you are relating that to math I could say, like, when we use, like, online manipulatives. When I know of them, I Google. I don't know of any [programs/simulations]. There is one program, and I'd have to look it up cause [sic] I used it last year. I forget what it is, and I would have to go in my files to find it. Whenever I'm teaching things I Google, so it's not like I have a set list that I could go to for manipulatives.

Isabell needed a description or definition of a simulation; she then compared it to an online manipulative, which she expressed interest in using. Her main problem was a lack of knowledge about math manipulative resources.

Teachers' technology knowledge was not only limited to simulations; it transcended to what they considered technology. Items such as cell phones, digital video recorders (DVRs), and televisions were not considered technology; only computers, laptops, and tablet devices were seen as technology. This belief led Jake to note that he spent only 15% of his time with technology and Isabell, 25% of her time. Yet, they both indicated that they constantly are on their laptops and using their cellphones and that they DVR multiple television programs. Isabell even noted that she streamed live sporting events through the Internet when the events were not available to watch on television. The

affordances of using everyday technology in the classroom was not apparent to either of these teachers.

Perception of technology. Teachers' own ideas or perceptions of how the technology could be used in the classroom was a second internal barrier. When teachers only see the technology as a tool they must use as opposed to a device that could enhance their instruction, the use of the device is limited. Isabell demonstrated an example of this perception barrier in her views of using both the iPad and the Smartboard in her classroom to aid in instruction. From her perspective, there was still a lot of value in paper-and-pencil practice, something she did not necessarily see in either the Smartboard or the iPad:

Smartboards. I don't, um, use them as much as I could because I don't feel like I don't have the knowledge of them in depth to use them as much as I could in a math classroom. Because I feel like if I'm gonna be really utilizing technology, Smartboards, I feel like, are more beneficial to me than the iPads at this point in time, but I don't use it as a Smartboard, I use it as a projector.

Isabell's perceptions about the integration of both Smartboard and iPad technology could be connected back to her lack of knowledge. She still felt that the Smartboard technology was a more valuable technology tool than the iPads, even though she was utilizing it only as a projector. In classroom observations, Isabell did not use the Smartboard function during instruction. Upon inspecting the Smartboard pens we found the batteries were dead, and the Smartboard software on her computer needed updating. The possible uses of the Smartboard had been diminished due to the lack of upkeep and knowledge about how to maintain and use the technology.

Isabell was not aware of the affordances of the iPad beyond a note-taking tool. She mentioned during the interview that the students could not take their iPads home, so taking notes on the iPad in class would not be effective since students would not have access to them while working on their homework. This type of use also established a teacher-driven classroom, one where the teacher is the keeper of the knowledge that must be then be distributed to the students by the teacher.

Jake had a similar teacher-driven pedagogical approach to teaching. During instruction, Jake conveyed information, typically vocabulary, to the students. There was little opportunity for science inquiry where students could explore and move at their own pace to discover information for themselves. Jake was observed performing demonstrations for his students on a few occasions, as in this vignette quoted from our field notes:

Jake stood at the front of the classroom and did an experiment as the students watched from their desk; occasionally Jake would call upon a student to assist him. For example, during a conduction lab students were given the opportunity to feel the different utensils that had been sitting in the boiling water. Students were instructed to take notes on their iPad about what they had observed. Later that week students used the Poplet app to create a concept map about conduction, convection, and radiation.

Jake's teacher-driven pedagogy limited the use of the iPads in his classroom. Though as the school year progressed and Jake had the opportunity to experience different iterative learning cycles with the research team, his pedagogy was observed to be moving slightly toward a more student-centered instructional approach.

Perceptions of practice vs. actual practice. Individual barriers can also include the teachers' perception of how they and others around them are using the technology in their classroom instruction. We observed that the teachers' perceptions of how they used technology was often different than their actual practice. The teachers' perceptions of others' technology use also varied based on how teachers viewed and valued technology in classroom instruction.

During Jake's circle of influence interview he indicated that iPads, QR codes, and specific websites such as [Bob the Alien](#), [Enchanted Learning](#), and [Pete's PowerPoint](#) site were the most influential technology pieces on his teaching practice. Jake placed these four items the closest to the circle, which indicated a higher influence on practice (see Figure 4). He justified the placement of the iPads due to the fact that "we are trying to be a one on one." Jake used a similar superficial justification when he moved the QR codes close to his circle of influence. (**Editor's Note:** Website URLs are provided in the [Resources](#) section at the end of this paper.)

QR codes are actually interesting because you're suppose to be 13 to actually access them. So, my kids are not 13 and you will see a disclaimer that says you need to be 13. You have to be able to do the consent thing. I will put the QR codes pretty close by, even though there is that disclaimer. The kids really enjoy the QR code, the technology of being able to scan something.

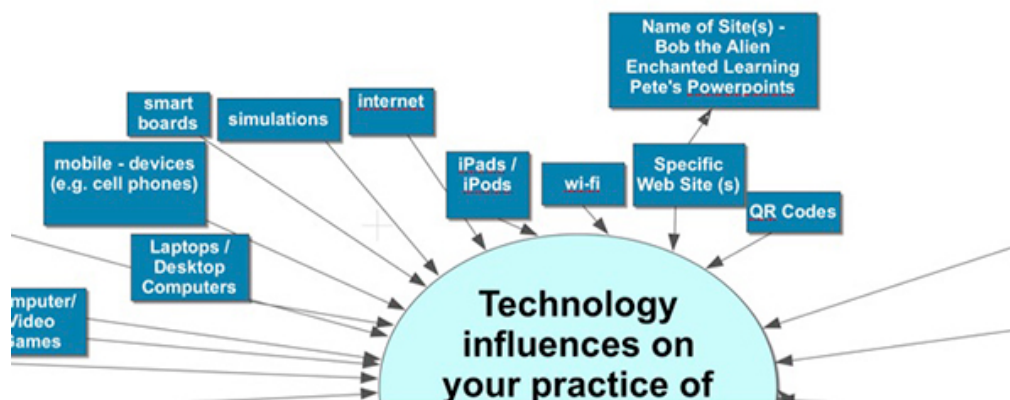


Figure 4. Jake's QR code example – Jake's perceptions. (Click on the image to view a larger version.)

Jake described the technology as something the students' enjoyed; however, the use of QR codes was not observed in Jake's classroom. Jake's indication of websites that influence him was different than the observed websites. We did not observe Jake using any of the websites he mentioned in his interview. He regularly used [Brainpop](#), [Discovery Learning](#), and [Quizzlet](#) to support his instruction (see Figure 5). Jake also used [AAAS](#), a question creating web source that creates test questions aligned with the state end-of-year exam. On a regular basis Jake was observed using his laptop, the Internet, and video clips to support his instruction. Nevertheless, he did not indicate these items as being influential components of his classroom pedagogy on his circle of influence.

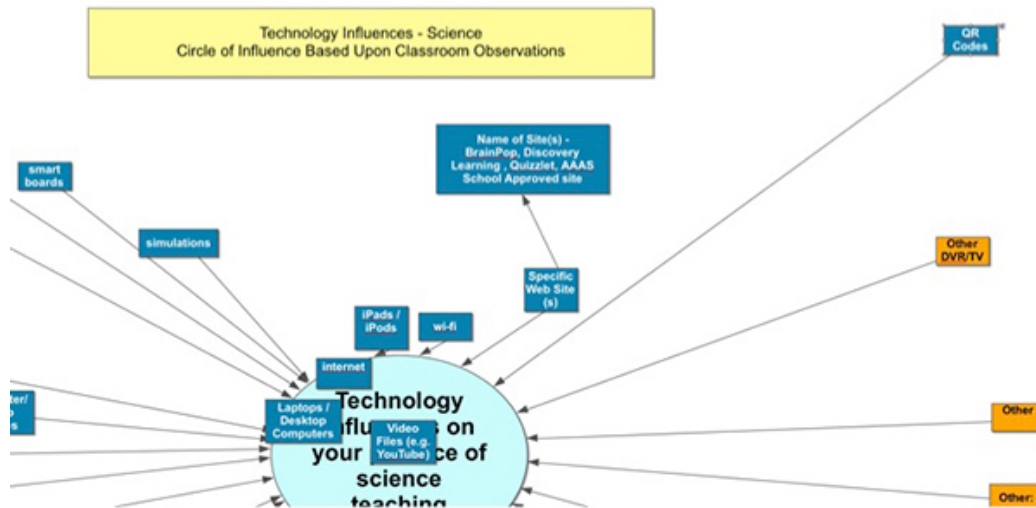


Figure 5. Jake's QR code example – researchers' observations. (Click on the image to view a larger version.)

Likewise, Isabell had anomalies between her circle of influence placement and the observed use of technology in her classroom. Isabell stated in her interview that she used her laptop and Smartboard mainly as a projector during her classroom instruction, which was observed multiple times upon visiting her classroom. These technologies, along with the word processing program, were the only forms of technology observed during classroom visits. Isabell designated on her circle of influence that many different forms of technology, such as podcasting, social media, Smartboard, and the Internet, were very influential on her teaching practice. These forms of technology were never observed being used for classroom instruction. As noted earlier, Isabell did not know what simulations were, though she placed this item relatively close to her circle of influence in comparison to things such as QR codes and calculators, which she had used previously with her students (see Figures 6 and 7).

Through the interviews, both teachers indicated that iPads were very influential for their teaching, but at the same time, Isabell specifically stated that she did not see how the iPad could be used successfully in math instruction: "Technology is difficult to use in math class because the students need to work out the problems and I really do not see a reason why the iPad needs to be used everyday."

The perception that math always had to be worked out on paper was a barrier for Isabell. She did not see the potential for teaching and learning math in a different way. Isabell did show an interest in using more technology, but only if she deemed it the best possible means for instruction, as was shown during the interview:

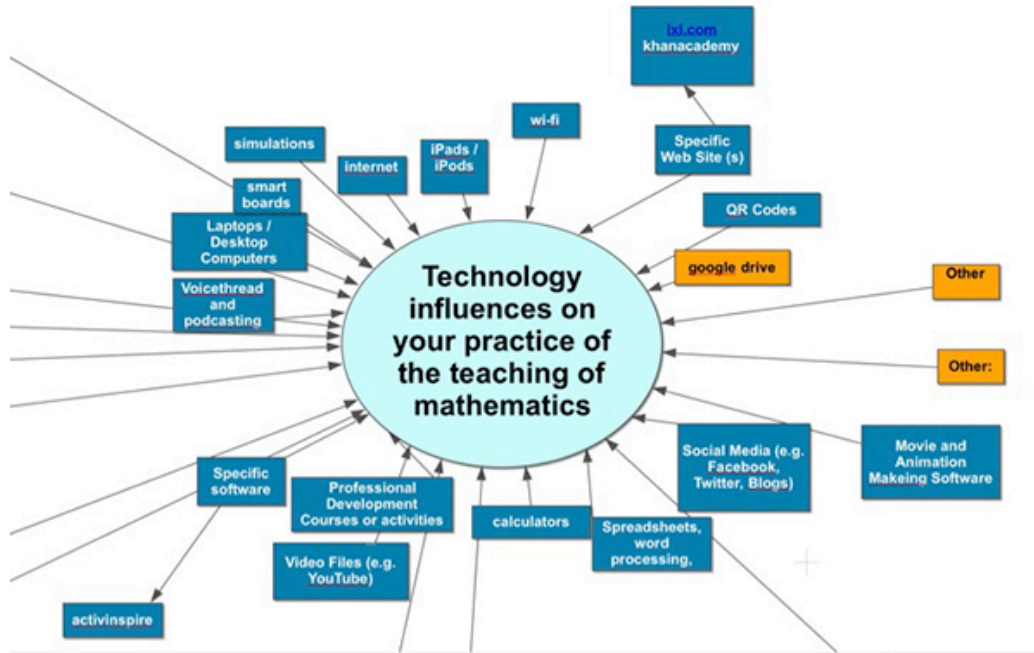


Figure 6. Isabell's inner circle of technology influence.

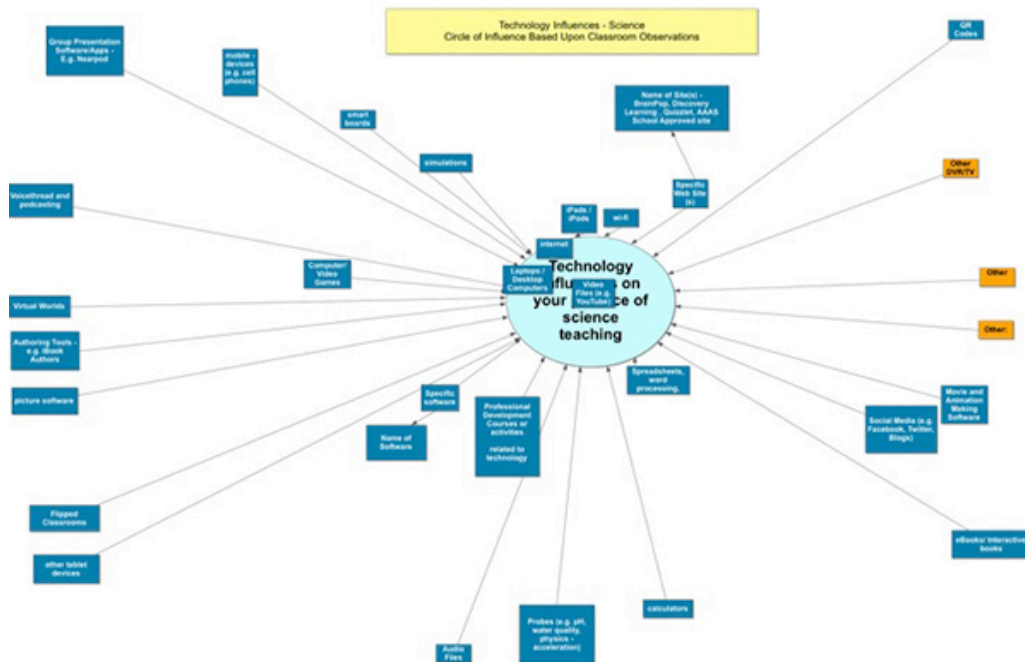


Figure 7. Researchers' classroom observation of Jake's practice and technology integration.

I would like to see, you know, that I feel like I can do every piece of my lesson that needs to be done, you know, that the technology is the best means for it to be doing it on there.

Isabell was not convinced that technology, in this instance the iPad, was the best way to teach her curriculum content. Her perception of good mathematical pedagogy was that math would be taught through direct instruction with notes and practice problems. Jake, however, saw value to using the iPads in his classroom and content area, which changed over the course of this study. Jake attempted to use the iPads to have the students create concept maps, complete webquests, and play games through the website Quizlet. During the interview Jake talked about an Internet site that could be used in his class that used the technology in different and unique pedagogical context.

And this was something that was brought to my attention last year during a teacher conference, a science teacher conference. They have an app or a platform or a website called Fakebook that's very similar to Facebook, its done on the same model, the same structure. But you would, like, pick up a personification of something. Like maybe you would pick up the personification of sound and that would have sound's friends and who sound has been in contact with and little conversations that go back and forth, likes and dislikes. I haven't spent time to explore it, but it seems like something that the kids would enjoy.

Even though Jake identified this unique platform as something the students would enjoy, he had not used this identified format in his classroom. Instead, he had stuck to having students create concept maps using the Poplet app. The science content webquests that Jake had his students complete dealt mainly with identifying information through web searches. We observed over the course of the school year that he used the iPads more but stayed within his area of pedagogical comfort. Despite the increased integration of the iPads, Jake still valued other forms of instruction over this integration:

And we do use the Internet quite a bit. One thing that I like to do is I like to do a web search and find something that is going to be kid friendly. Cause it really is what I talk to the kids about, its, um, there's times where I tell them you really need to be using this book [points to textbook] because the book is tailored for a sixth-grade reading level.

Jake still held more value in using the science textbook than on using the plethora of resources made available through the iPads. The reliance on the same activities displayed Jake's reluctance to move from his comfort zone. He was willing to use the iPads more in his science classroom, but he was not ready to make a transition to implementing the iPad in an inquiry-centered way.

Niess (2005) suggested that because teachers have limited experience with learning their subject matter with technology they tend to rely on more traditional methods within their classrooms. The focus on using the science textbook, which is outdated, as a good source of information because of the reading level further exhibited Jake's lack of available technological knowledge and experience with learning with technology. If he would increase his knowledge of the available apps, iBooks, and resources on the Internet that exist at a suitable reading level for his students, Jake may find himself less reliant on the outdated textbook material. It may also broaden Jake's integration attempts as he becomes more familiar with science content through the use of technology.

Value of technology. Hughes (2005) determined that when teachers experienced more content-specific examples in workshops and professional development, they were more likely to see the value of the instruction and replicate it in their own classroom. The ways technology was valued at Caldwell Middle School created an interesting dynamic between technology use and pedagogy. According to both Jake and Isabell, the teachers had been instructed by the administration that the iPad should be used 45 minutes a day during the 60-minute class period. There was, however, no emphasis on the pedagogical quality. Instead, the focus was on the technology and the duration of use.

Isabell indicated that she felt as though she was “the slacker” of her sixth-grade team because she did not have the students use the iPads as much as the other teachers on her team. When asked to elaborate, she did not indicate what types of instruction the other teachers were engaging in with the iPads; instead, she mentioned only that both the English language arts and science teachers appeared constantly to have the students working with iPads in front of them. This brought us to question whether instruction might improve with content-specific pedagogical coaching. Jake stated, “There are sometimes that I find myself trying to just come up with an activity that will use the iPad where something else could be just as effective if not more effective.” Isabell voiced similar concerns:

I have no problem with using it all the time; I just need to feel like it’s the best way for them [the students] to be learning the concept. You’re told you need to use it [the iPad] so often and I honestly, and people disagree with me. I don’t believe it should be used every day anyway in the math classroom. I think that there is value to doing things on pencil and paper and having them [the iPad] with you at all times, and I was overwhelmed. And I’m still overwhelmed this year because they’re [administration] saying they’re going to be coming in and watching, and I’m not using it nearly as much as I should be using it.

She also stated multiple times the difficulty that students had with the curriculum. She believed that ensuring that she covered the necessary objectives was most important to her:

If it’s between me getting the curriculum done and me going further and doing something fun, I’m going to choose getting the curriculum done. Which is an issue I run into. But I feel like by the time I would be ready that they would be ready to do it, I would be, like, ready to move on. We just have a huge curriculum our kids are very behind, and it takes just so much to get them to the basics, which is a problem with my teaching, in general. Because I need to be doing more higher level and I can’t always get there. Sometimes you can start out higher level, but a lot of times you need to get them there.

Until direct connections to the content areas are made for the integration of technologies such as iPads as a pedagogical tool, teachers like Jake and Isabell will continue to push back against the integration, relying on traditional methods and pedagogies.

Conclusions and Implications

During the early phases of this design-based study, themes emerged from a science and a math classroom that provided insight to the implementation of 1:1 iPads at Caldwell Middle School, at least from the perspectives of these two teachers. An analysis of this early data demonstrated rudimentary evidence of both external-first order and internal-second order barriers (Ertmer, 1999, 2012). This study suggests that some science and

math teachers, despite working in a 1:1 environment, still face many of these barriers when trying to integrate technology into their pedagogical design and practice.

Data demonstrated that these barriers were particularly evident in the classrooms of Jake and Isabell. External-first order barriers (Becker, 1994; Ertmer, 1999; 2012), such as connectivity, app acquisition, and lack of adequate professional development, became sources of frustration for Jake and Isabell and were typically reflective of the school at large. These frustrations created deterrence from further integrating the iPads into instruction, thus negating the potential affordances the iPads were meant to provide. Challenges like these led Jake, Isabell, and the other Caldwell teachers to view the iPads as an external, and often irrelevant, component of their instruction.

Further, our findings suggest that internal barriers created obstacles to iPad integrated teaching. This was particularly evident in Jake's science classroom. Internal barriers, including self-efficacy, beliefs and values of technology, impacted how TPASK /TPACK (Jimoyiannis, 2010; Koehler & Mishra, 2006) was enacted in Jake's practice. While Jake exhibited strong self-efficacy with respect to his science knowledge it was not observed in either his technological knowledge or in his pedagogical knowledge with respect to constructivist, inquiry-based practices of science.

The assumption of the research team going into this study was that science knowledge and its subsequent pedagogy would unfold organically, but it did not with Jake. Jake's classroom was teacher centered; rather than have his students participate in open-ended inquiry, he would demonstrate inquiry experiences for them, creating a passive learning environment where students did not engage with science. Hands-on science became hands-off. His limitations resulted from his own internal barriers (e.g., self-efficacy or confidence) in both pedagogical knowledge involving inquiry and technological knowledge integrating iPads. These limitations impacted how the iPads were integrated into his classroom instruction.

While not as prevalent, Isabell exhibited similar barrier issues with respect to technological knowledge. These ideas are supported by the literature on TPASK (Jimoyiannis, 2010), TPACK (Koehler & Mishra, 2006), and institutional barriers (Ertmer, 1999; 2012).

Additionally, from our analysis, a dichotomy emerged between teachers' perceptions of technology integration and observations of practice. Technology applications, like the QR codes noted by Jake, were frequently described in interviews, but were overwhelmingly absent from practice. This phenomenon can be traced back to Jake's self-efficacy as it related to both technological knowledge and pedagogical knowledge. We also posit that teachers', including Jake's and Isabell's, understanding of the interactions of content knowledge, technological knowledge, and pedagogical knowledge resulted in integration of the technology in ways that did not always enhance the science content learning.

While at this stage of our design study we cannot definitively assess student learning, we have observed that when new applications (i.e., technological knowledge) and methods (i.e., pedagogical knowledge) were introduced and modeled in their classroom, teachers like Jake and Isabell began to extend their practice beyond their traditional comfort zones, creating new classroom environments that engaged their students differently from what we had previously observed. Students moved from being passive participants to active science learners.

After the Sound Inventory and Plate Tectonics inquiry investigations were modeled and implemented in Jake's classroom, we noted that he began to integrate the iPads more frequently in his pedagogical practice. While his choices were still limited and often became teacher directed, he was beginning to demonstrate increased confidence and self-efficacy thereby decreasing his internal barriers to technology integration. Content-specific PD and support that focus on science content, technological knowledge, and pedagogy may be important to the successful integration of technology in science classrooms. Given the appropriate scaffolding, teachers like Jake and Isabell may develop their self-efficacy in both their technological knowledge and pedagogical practices, resulting in more engaging learning environments for their students.

The Next Generation Science Standards (Achieve, 2013), called for an increase integration of technology to emphasize the relationship between science, engineering, and technology. This recommendation is relevant in the science classroom, where technology plays an important role as a tool for scientific inquiry, visualization of abstract concepts, developing models, and communicating ideas to others (Park & Slykhuis, 2006). The teachers in this study did not necessarily see this relevance due to the barriers that they perceived, both external and internal. Externally, teachers in our study still had issues obtaining apps necessary for science instruction. However, internal barriers were most pervasive in their integration of the iPads into instruction.

Issues of self-efficacy with technological knowledge and pedagogical implementation of the technology were at the forefront with all of our teachers, resulting in inadequate integration of the iPads. The belief that students could learn through this integration and the teachers' value of its use in the classroom was disconnected from administrative demands. Jake and Isabell, like many others at Caldwell, would integrate technology to fill a demand rather than enhance instruction. While the importance and value of technology was acknowledged in everyday life experiences, the teachers did not always make the connection to classroom practice.

The primary affordances of tools like the iPads in this 1:1 initiative in science and mathematics classrooms may be their power to engage students in the use of tools that provide mechanisms and contexts to think through complex science topics. The challenge may be, in moving forward, that teachers do not always see these devices as tools that can enhance their pedagogical instruction in these areas. The key will be to help those individuals, through content specific PD and scaffolding, to recognize the power that these tools provide. While still in its early stages, possibilities emerged from Jake's response to early modeling-implementation cycles. Given the right supports, the iPads can be used as a way for teachers to engage students in science learning. Though we have not yet found the ideal way to bridge this gap in integration, these findings will help us to continue to refine the practices and integration of the iPads as an instructional tool in science and mathematics classrooms with teachers like Jake and Isabell.

This study provides early insight into how tools like the iPads found in this 1:1 initiative can help teachers, specifically science and mathematics teachers, engage and enhance student learning. It also provides us with insights into the challenges that have emerged in the classrooms of schools that are implementing these initiatives. It is our hope that continued work in these classrooms will help reveal the areas of PD that are necessary for successful integration in science and math classrooms.

Future studies should seek to examine the impact of identified PD experiences on how teachers integrate and utilize iPads in their classroom. We also aim to analyze the impact on student learning in science and mathematics, examining the connections between technology, content, and student understanding. This study suggests that content-based

PD for iPad integration may be beneficial in helping teachers to think about TPASK/TPACK, creating the opportunity for enhanced integration of the iPads within science instruction.

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Resources

AAAS - <https://aaas.org>

Bob the Alien - <http://www.bobthealien.co.uk/>

Brain Pop - <https://www.brainpop.com/>

Discovery Learning - <https://www.discoverylearning.com>

Enchanted Learning - <http://www.enchantedlearning.com/Home.html>

Pete's Powerpoints - <http://www.pppst.com/>

Quizlet - <https://quizlet.com/>

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Appendix TPACK Teacher Interview

iPad Project

Participant ID _____

Date of Interview: _____

Content Discipline: _____

Hi. My name is: _____. Thank you for helping us out. We are interested in looking at the how technology is integrated into the curriculum at Lowes Grove Middle School. To achieve this goal, we are asking teachers like yourself what you think about your content areas, pedagogy and technology integration and how it is represented here at Lowes Grove. This interview will last around 45 - 60 minutes. It is important to note that:

- No other teachers or administrators will have access to your comments. We will be reporting general trends only
- there are no right or wrong answers to these questions. We only want to know what you think.

Also, please feel free to say what you think about the question. These are designed to provide you with a voice in shaping technology integration at Lowes Grove. Do you have any questions of us?

Circle of Factors and Influence Activity

Role of Technology in own life

1. If you pictured your life as a pie, what piece, if any, would technology occupy?
 - a. How do you see technology impacting your daily life?
 - i. Probe for responses (e.g. did you drive to work today?)
 - b. Can you examples?
 - c. How does technology impact (or not impact) how you view the world?
2. What are your primary sources of technology information?
 - a. What types of “technology” websites do you visit? Magazines read? Books? TV programs?
3. Did you ever consider pursuing a STEM (Science, Technology, Engineering and Mathematics) career? Why or why not?
 - a. If no, what prevented you from pursuing this career path?
 - b. If yes, what caused you to change your career path?

4. What types of technology do you engage with on an everyday basis?
 - a. Do you consider yourself to be proficient in technology use? Why or why not?
 - b. What types of technology do you feel most confident using?

Preparation and Collaboration

1. How do you think your teacher preparation program helped you in developing as a science teacher?
 - a. What would you have liked to have seen /taken/been exposed to?
2. What role did technology play in your preparation?
3. How do you work with other teachers in the planning and teaching of _____ and the use of technology?
4. What is your perception about the value that your school district places on the teaching of _____ and integration of technology?

PART II: Can be done same or different day depending upon how long part I went. **Role of and Technology in Instruction**

1. How is _____ instruction the same, or different, from other content areas that you have to teach?
 - a. What makes it different (or the same)? Can you give me an example?
 - b. What do you feel is the best way to teach _____?
 - i. Can you tell me about a lesson that you feel particularly demonstrates this?
 - ii. What was your students' reaction to this experience?
 - iii. How and what did the students learn? In other words, how did you assess student learning (beyond benchmarks, EOGs)?
2. What _____ content do you feel is most important for students to learn in your classroom?
 - a. Do you feel that the state standards address this? If not, how could they be changed?
 - b. In what areas of _____ you do feel confident teaching? What areas most intimidate you?
3. What types of strategies do you use to engage your students in _____?
 - a. What types of materials help facilitate this?
 - b. If you could have any materials that you wanted, what would you request?
4. If I were to walk into your classroom, what would I see? What would the students be doing? What would you (and your TA) be doing?
5. How do you connect _____ to your students' lives?
 - a. What types of speakers? Field trips? Activities? Afterschool experiences?
 - b. What are the benefits for students in participating in _____?
6. How do you see _____ being integrated into other content areas?
7. What do you see as the role of technology in your classroom? How specifically is it integrated into your current classroom?
 - a. What specific types of technology are you integrating? How often?
 - b. What types of software/websites are you using?
 - c. How much is class- based vs. media lab?
 - d. How would class access modify how you use technology?

8. Are there some problems that you encounter when using computers and technology with your class? Tell me about them and things that you think will help the situation.
9. How do you think technology helps students learn? How do you assess that learning?
10. What kind of access do your students have (or not have) to technology outside of school?
11. What role do you see gaming playing in future classrooms?

Circle of Influence of Technology on Science Teaching Practice

