TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE: RELATIONSHIPS TO LEARNING ECOLOGIES AND SOCIAL LEARNING NETWORKS

A DISSERTATION
SUBMITTED TO THE SCHOOL OF EDUCATION
AND THE COMMITTEE ON GRADUATE STUDIES
OF STANFORD UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

Karin Sigrid Forssell
August 2011

Karin Sigrid Forssell

I certify that I have read this dissertation and that, in my opinion, it is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy.

(Brigid Barron) Principal Adviser

I certify that I have read this dissertation and that, in my opinion, it is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy.

(Shelley Goldman) Co-adviser

I certify that I have read this dissertation and that, in my opinion, it is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy.

(Hilda Borko)

Approved for the Stanford University Committee on Graduate Studies.

For Nika.

ABSTRACT

Improving learning experiences for all students is the ultimate goal of research in technology use in education. The U.S. National Educational Technology Plan calls for the use of new technologies to "provide engaging and powerful learning experiences, content, and resources, and assessments that measure student achievement in more complete, authentic, and meaningful ways" (U.S. Department of Education, 2010, p. ix). With more availability and better usability of technology in schools, the potential for teachers to use these tools in their teaching is greater than ever. However there is well-placed concern that even when good technologies are available, they are not being used to their full potential to support students' learning. A key factor determining whether new technologies are adopted is the extent to which teachers know how to use them to support students' learning. The special knowledge of how technologies can support students' learning of subject area content is known as technological pedagogical content knowledge (TPACK; Mishra & Koehler, 2006). The need to understand how teachers learn TPACK drives the research questions in this dissertation. I address this need through a study of accomplished teachers' confidence in their TPACK.

In this study I explore the relationship of accomplished teachers' TPACK confidence to their use of technology with students and to their teaching and learning contexts. The analyses focus on the responses to an online survey by 307 teachers who achieved National Board Certification in California. These teachers, from across subject areas and grade levels and with a wide range of experience, provided information about the frequency and breadth of their computer use with students; their use of computers in their personal lives; the school, classroom, and personal resources available to them for learning; and the people in their learning networks who support their learning to use new technologies for teaching. Although the representativeness of the sample was limited and the measures self-reported, they provided rich opportunities to discover relationships and suggest avenues for supporting teacher learning of new technologies.

Analyses showed that these accomplished teachers' confidence in their knowledge of how to use new technologies *for teaching* was different from their confidence in using technologies more generally. Further, TPACK confidence related to student use of computers in the classroom. Although there was a small positive relationship to frequency of computer use, a stronger relationship was found to teachers' exploration of activities in class. Teachers with higher TPACK confidence were likely to have explored a greater breadth of activities related to 21st century skills with their students.

Exploration of the teaching and learning contexts of teachers with different levels of TPACK confidence showed no significant differences between teachers of different ages, genders, grade levels, subject areas, or student populations. However, confidence in teaching with technology did relate to measures of the teachers' learning resources. The range of different resources, number of supporters, the breadth and the amount of support provided were higher in high-TPACK teachers. Higher levels of school and classroom computers were also associated with higher TPACK confidence, suggesting that computers might be not only a resource for teaching, but for teacher learning as well.

Analyses of teachers' learning networks and the support accessed through them showed that the vast majority of learning supporters were in the school setting, and that the most common types of support involved sharing knowledge, modeling, and explaining a vision of technology use. The least common types of support involved providing physical and monetary resources for learning. Three more types of support involved initiative on the part of the teacher, and awareness of the teacher's goals on the part of the learning partner. These types of support – learning together, posing challenges, and connecting the teacher to others to learn from – were significantly more common among high-TPACK teachers. Furthermore, learning partnerships within school and other professional settings were a key feature of the learning environments of high-TPACK teachers; further research is needed to understand whether higher confidence leads to more learning partnerships, key partnerships lead to learning opportunities that increase confidence, or some other factor increases both.

These findings suggest several potential leverage points for the design of learning opportunities for teachers. Because confidence in TPACK is different from confidence in using technology more generally, it is important to create opportunities for teachers to learn how new technologies support their specific goals in the grade, subject area, and school context in which they teach. The findings that TPACK confidence relates to a breadth of activities and to higher numbers of school and classroom computers suggest that exploration of new applications in situ may be a key part of developing confidence and exercising judgment about which technologies support student learning. The nomination of learning supporters from multiple settings, and the relationship between TPACK confidence and teacher laptops, suggest that flexibility in time and place of learning may be important.

This dissertation supports current recommendations in teacher professional development for collaborative learning experiences for teachers, while recognizing that direct instruction in technology is the most common form of learning support. The findings suggest that key types of support from individuals in a teacher's learning network may be particularly valuable, as they provide a collaborative, context-sensitive, and individualized support in a potentially long-term learning relationship. Based on the learning ecologies framework, this study points to ways in which learning partners outside of the immediate school setting might provide important forms of collaborative support, through connecting learners with others to learn from, and by posing challenges to learn something new.

I conclude that TPACK is a useful and important construct. From all the perspectives explored, the TPACK confidence measure captures distinctions that we care about. However, the study's limitations point to important areas for future research. The correlational nature of these analyses raises questions about the nature of relationships, such as the one between TPACK confidence and resources to support learning. Do learning resources lead to confidence in knowledge, or does confidence lead to awareness of existing resources? The low response rate limits the generalizability of the results to this sample, raising the question of how far these results apply to other groups of teachers, including those with less pedagogical content knowledge (PCK). Should TPACK be measured without first assessing the participant's PCK? And the use of a self-rated TPACK measure raises questions about the relationship of participants' confidence to objective knowledge measures. How might we develop survey measures that reliably capture the complexity of technological pedagogical content knowledge?

Findings in this study point to ways we might further understand, and subsequently increase, teacher confidence in using new technologies to support student learning. Understanding TPACK and the conditions under which it develops is an important field of research, as we strive to help teachers learn to use new technologies effectively to support powerful student learning.

ACKNOWLEDGMENTS

In planning, executing, and reporting this study I was blessed by the support of many wonderful people in my own "social learning network." With a laugh I realize that they gave me many of those same types of support that were associated with higher confidence in knowledge in this study: challenging me, collaborating with me, and connecting me to others to learn from.

Pose challenges for me to find answers to

Early challenges came from my dedicated middle-school teaching colleagues, who pushed me as technology mentor to think deeply about technology use in schools. I learned a great deal from my search for answers to their questions. They inspired me to think of teachers as learners. I am indebted to many who provided early feedback on everything from big ideas to the phrasing of survey questions.

More recently these questions have also come from my students in the Learning, Design, and Technology MA program at Stanford's School of Education, students with a passionate desire to find ways to leverage new technologies to solve important learning problems. Their quest to make a difference has pushed me to go farther and dig deeper into the literature and my own data to find suggestions about how we can make learning experiences more effective.

Learning with me

My fellow students have been a wonderful resource from the beginning of my doctoral studies. My Psychological Studies in Education cohort of 2005, members of the YouthLAB research group, peers in the LIFE Center, and students in the Learning Sciences and Technology Design program discussed coursework, debated ideas, and gave feedback on early findings. The people who can tell you when your presentation of ideas doesn't make sense are precious.

I especially thank and acknowledge the members of my dissertation support group. Angela, Cathy, Heidy, Kathleen, Leah, Lindsay, Marily, Maryanna, and especially Ugochi, I wouldn't be where I am without you. Emma, my academic "big sister," I appreciate your generosity in sharing your own learning with me—both inside and outside of school—more than I can say. I look forward to continued collaboration.

Connecting me to others to learn from

Although I learned a great deal from the extensive expertise of my advisors, they also played a key role in connecting me to others. I deeply appreciate the advice of my advisors Brigid Barron and Shelley Goldman, who pushed me to connect my ideas to those of other scholars, expanding my understanding of the relevance of my work. The support of reading committee member Hilda Borko and dissertation evaluator Pam Grossman helped these ideas develop and mature. Counsel from professor emeritus Decker Walker and the LSTD faculty members provided me with not only references to scholars whose work was relevant to mine, but also insights into the work and profession of academics.

There are two more acknowledgements I need to make. First, I am deeply indebted to the many individuals who spent time and effort on thoughtfully answering the questions in my survey. I calculate their combined time spent in the hundreds of hours, and I hope that they find some satisfaction in knowing that they contributed to the findings presented here. I hope that this work will contribute to the learning of all teachers and the children they teach.

And finally, my family. My parents, my sister and her family, and my extended family have cheered me on, supported my efforts in ways both large and small, and never doubted that my work was worth doing. I dedicate this dissertation to my daughter Nika, who constantly reminded me that my goal is to support the miracle of learning.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1: Introduction

The Call for Technology Use in Education

Billions of dollars have been spent to bring digital technologies to classrooms in the United States, yet the calls for technology to transform education continue. Technology can be used to support many high-level education goals: increasing student learning, making school engaging and relevant, providing equitable access for disadvantaged populations, communicating between school and community to support students, supporting teachers' professional growth, and holding schools accountable for student outcomes (Zucker, 2008). The National Education Technology Plan, recently released by the U.S. Department of Education, calls for revolutionary transformation of our education system through the use of technology, saying

> …we must leverage it to provide engaging and powerful learning experiences, content, and resources and assessments that measure student achievement in more complete, authentic, and meaningful ways. Technology-based learning and assessment systems will be pivotal in improving student learning and generating data that can be used to continuously improve the education system at all levels (2010, p. ix).

Technology is a broad term, chosen because the specific tools are changing all the time. However, for most purposes, the technologies in question are digital, most often computer-based. Right now, digital images allow source materials to cross boundaries of time and space; immediate feedback allows students to practice the skills they need; creativity tools allow students to translate their understanding of concepts into a variety of media; social networks and other publishing resources allow learners to not only consume, but to contribute content; simulations and games allow students to test hypotheses and explore high-consequence scenarios in a low-risk environment. The federal government has supported the effort to bring these many types of technology into classrooms in a variety of ways. For example, through Goals 2000 and the Enhancing Education Through Technology (EETT) Act, money and political resources were provided to schools and districts. The Preparing Tomorrow's Teachers for Technology (PT3) program supported technology instruction in teacher education programs. States have added technology to teacher credentialing requirements, while also creating Educational Technology Plans and Technology

Standards for education (Zhao, 2008). Computers and Internet access have been brought to schools, with the result that the National Center for Education Statistics reports that 97% of public school teachers have at least one computer in the classroom every day (Gray, Thomas, & Lewis, 2010). With the recent development of rugged, cheap laptops, and versatile tablet computers, there is reason believe that computer access will continue to rise, with computers soon to be ubiquitous as “school supplies.”

Do Teachers Want to Use New Technologies?

Whether or not teachers want to use new technologies is open to debate however. A recent press release from the Public Broadcasting Corporation reports that 76% of K-12 teachers use digital media in their teaching (Grunwald, 2010). The MetLife survey of American teachers shows that 62% of teachers use the Internet to get teaching ideas at least once a week (Markow & Cooper, 2008). The Gates foundation published survey results (2010) showing that 93% of teachers agree strongly or agree somewhat with the statement “Digital resources such as classroom technology and Web-based programs help my students’ academic achievement.”

Yet a large number of studies have demonstrated that many teachers don’t use the technology they have to support student learning (e.g., Cuban 1986, 2001; Means 2004; Palak & Walls, 2009; SimCalc 2007). Researchers have suggested a number of reasons why teachers might find new technologies difficult, disruptive, or simply undesirable in their teaching (e.g., Cuban 1986; Norton, McRobbie, & Cooper, 2000; Zhao & Cziko, 2001). For example, the same political will that has supported technology use in schools through the Enhancing Education Through Technology Act (NCLB, 2002), has created a climate of accountability that works against its use. When tests disallow the use of technologies (such as calculators or word processors), the teachers face a conflict between preparing students to do well on the test under actual testing conditions and teaching in a manner supported by technology. A teacher expressed the frustration with this constraint eloquently: “When you do your driving test they don’t test you in your horse and cart” (cited in Hennessey, 2005, p. 172). This is only one of many reasons teachers might choose not to use new technologies for teaching. Even in technology-rich Silicon Valley, many teachers believe that “an expert teacher can teach well without technology.” Much as proponents of computer use in schools extol the potential for better learning outcomes, it is not clear whether teachers agree that using them is worthwhile. Why then would teachers invest their time, energy, and limited resources in using new technological tools?

The disconnect between technology's potential and its implementation raises many questions about the nature of teachers' decisions to use new tools in their teaching. In many of the studies of technology use in education, teachers are seen as gatekeepers (e.g., Ertmer, 2005; Zhao, Pugh, Sheldon & Byers, 2002) who decide what technologies are appropriate to support learning, and when students may use them. They decide whether and how to use a new technology, with its inherent risk of failure, in the classroom. Those decisions are based on their understanding of how those technologies support student learning.

Knowledge of How to Teach with Technology

Learning how to use technology effectively to support student learning is time-consuming, because the nature of the problem of teaching with technology is "wicked" (Koehler & Mishra, 2008, p. 3). Wicked problems are complex, dynamic, and require understanding of multiple interdependent variables (Rittel & Webber, 1973). Two brief examples drawn from interviews with practicing teachers conducted in March 2010 will help to illustrate the many considerations that arise when innovating with new technologies in the classroom.

Regina, a seventh-grade Science teacher, developed a new way to use online animated cartoons with her students. Although she had used the cartoons as a motivational "quick introduction" or "wrap-up" in a whole-class context, she wanted students to be more directly involved in their own instruction. Regina signed up to use a cart of laptop computers in her classroom. She prepared a paper-based task to reinforce the new vocabulary in the cartoons. She paired the students, guided them to the web site, and showed them how to turn on the captions. She showed them how to pause the cartoon to respond to the prompts. The noise level was high as science-related phrases blared from 15 speakers, and as a result of this activity, Regina wrote a grant proposal requesting ear buds to use with the computers. Regina reported that she would continue this innovation because "the students were so much farther along, with getting it, than when we did it the other way." She attributed this to the fact that when the students control the cartoon, “they stop when they’re confused, not when I think they confused, or when I see someone else in the classroom confused.”

Cathy described herself as someone who doesn’t use technology much. She didn’t check out the laptop carts; they “sounded so problematic” according to colleagues who used them. Nor did she take her classes to the computer lab, where “we’d lose ten minutes of class time” and “we’d have all those problems with students forgetting to save copies and losing their work.” She explained that she wanted her middle-school English students to write their drafts by hand, because the act of typing gets in the way of expressing their thoughts. She also wanted an early sample of their response to the assignment in their own handwriting, so she would know it was their own work. Yet Cathy wrote a grant asking for a class set of digital cameras to use with her reading students. She planned for the students to take the cameras home to document meaningful aspects of their own lives, which they would caption and combine in an online magazine. Cathy knew she would need some professional development to learn to use the camera software and to upload the projects to the Internet. The school’s art teacher promised to give pointers about how she teach her students to take good pictures. She was willing to go to this effort because the experience would be fun for the students, the students would be proud to share their work with peers, and because “photographs can be really powerful, and I think if they really had to think about writing about them, that would be a really good exercise for them.”

These teachers based their decisions about how, when, and why to use technologies with students not only on their knowledge of the technologies involved, but also on their knowledge of their students, their insights about technology’s use in the classroom context, and their understanding of how the students’ use of the technology would support their curricular goals. They considered the technology’s benefits against the various costs in time and equipment. They acknowledged that a successful integration of the new activity would require some preparation. This complex knowledge of how to use new technologies to support student learning, demonstrated by Regina and Cathy, has been called “technological pedagogical content knowledge” or TPACK (Mishra & Koehler, 2006).

Supporting TPACK

If there is a special knowledge base related to using technology for teaching, and technology is always changing, then a relevant question becomes how teachers stay current. In a survey of K-12 principals, 73% reported that they needed support with learning how to use technology to improve student performance (Gandera, 2002). If principals, the visionaries and leaders in schools, don't know how to use technology for teaching, who provides the support teachers need, and where, and how? This study set out to examine how TPACK relates to the learning environments of accomplished teachers, in the hopes that insights into the design of better learning opportunities for teachers would emerge. To guide my exploration I posed the following research questions:

1) What is associated with greater confidence in technological pedagogical content knowledge (TPACK)?

2) How do teachers with different TPACK confidence profiles vary in their teaching and learning contexts?

3) What is the nature of the relationship between teachers' TPACK confidence and the learning support they access through their learning networks, across settings in their learning ecologies?

Chapter 2: Background

In this chapter I consider what we know about teachers' decisions to learn new technologies to support student learning. The field of educational technology has long been interested in teachers and their choices, so to begin I explore the complexity of what knowledge needs to be acquired by teachers. I then consider what is known about the conditions under which teachers use new technologies, which provides some insights into the learning environments and resources that were considered in this dissertation. Finally, I explore perspectives on the ways in which teachers might learn from various people and places.

Knowledge Required

Using a new technology in the classroom requires teachers to learn. As Niess explains when describing the developmental process of Mathematics teachers acquiring TPACK, "These teachers are confronting an innovation – an innovation that integrates a new technology tool, new teaching and learning strategies, and a revision of how they know their subject matter content as a result of the availability of the new technology" (2008, p. 3). In Chapter 1 presented examples of two different teachers considering the use of technologies in ways that represent innovations for their classrooms. Regina and Cathy based decisions about how, when, and whether to use tools not only on their knowledge of online cartoons or digital cameras, but also on their knowledge of the constraints of a classroom setting, the types of learning afforded, the curricular content understandings supported, and the characteristics of students who might benefit from their use.

The TPACK Framework

Regina and Cathy needed to know more than how to work a camera or a web site. When teachers use technology to support student learning, they rely on a special kind of technology knowledge grounded in teaching. The idea that teaching with technology requires complex skills and understandings has been developed over the course of several years. Koehler & Mishra (2008) cite many scholars who have contributed to the development of this concept, sometimes calling it by other names such as integration literacy, e-PCK, technological content knowledge, or ICT-related

PCK, before it recently gained acceptance as “technological pedagogical content knowledge,” or TPACK (Mishra & Koehler, 2006). At the heart of the framework is the idea that using technology for teaching requires more than simply knowing how to use a given technology; it requires the understanding of how technology, pedagogy and content interact to support student learning (Figure 2-1). TPACK is the understanding of how a tool can be used – its features, affordances, and constraints – to uniquely support students’ learning of a given curricular topic or concept.

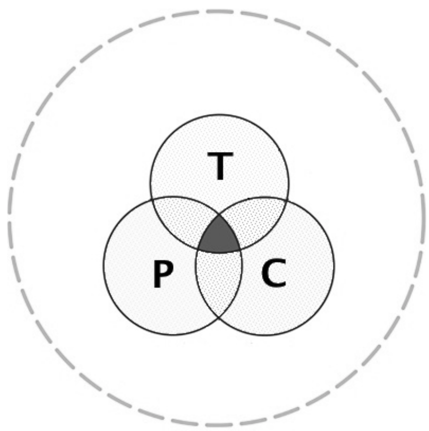

Figure 2-1. The TPACK Conceptual Framework. The figure illustrates the different knowledge bases related to pedagogy (P), content (C), and technology (T), and highlights the area where the three overlap. The dotted circle represents the context in which TPACK is embedded. Adapted from Mishra & Koehler (2006).

Why not just recognize that using new technologies is an expression of Pedagogical Content Knowledge (PCK)? The use of tools in effective ways that support student learning would be an example of strong PCK (Shulman, 1986). However, just as the PCK framework recognizes that there is teacher knowledge of pedagogy and of content, separate from pedagogical content knowledge, the TPACK framework highlights the forms of technology knowledge not embedded within PCK – those at the intersections with pedagogy (TPK), content (TCK), and independent of teaching altogether (TK). When we consider that teachers may learn to use technology in different ways, across different contexts related to teaching, disciplinary work, and their personal lives, the usefulness of the TPACK framework becomes clear: it focuses attention on different types of technology knowledge, used for different purposes. It may well be that these types of knowledge are distributed across different locations and social settings, which would be a critical insight when designing learning experiences for teachers.

Measuring TPACK

Recent scholarship in TPACK has focused on defining and measuring this construct. Assessing TPACK, the knowledge base of teachers, is difficult. Assessing PCK requires a detailed understanding of the pedagogical strategies that can uncover student misconceptions, the cognitive foundations of those misconceptions, and a variety of methods for supporting new learning (Hill, Ball, & Schilling, 2008). Similarly, assessing TPACK requires focus on a specific technology in a particular context and in support of a clear set of curricular objectives, and it will require some measure of teachers' PCK as well. The effort to develop measures of TPACK is proceeding on several fronts. While several scholars have begun the foundational work of using case studies to identify examples of teachers with TPACK (e.g., Ertmer, 2000; Hughes, 2005), others have attempted to identify boundaries in the framework through conceptual analyses (Cox, 2008). Using the TPACK framework, researchers have begun to develop surveys to administer to pre-service teachers (Schmidt, et al., 2009) and distance educators (Archambault & Crippen, 2009), as well as rubrics for observing TPACK-based technology integration (Harris, Grandgenett, & Hofer, 2010).

One challenge when assessing teacher knowledge in survey form is to adequately balance the details of the individual teacher's teaching assignment against the applicability of the survey questions to a wide range of respondents. Extensive work has shown the difficulty of accurately measuring pedagogical content knowledge (e.g., Hill, Shilling, & Ball, 2004); to do so at the same level of granularity with the added dimension of technology would require very specific survey items. A particular technology would need to be identified as well as a specific topic and developmental level. This work has been started but there is much still to be done (e.g., Krauskopf, Zahn, & Hesse, 2011). In the absence of more objective knowledge measures, self-ratings of knowledge are common. Studies from fields ranging from medical education to consumer research have explored the relationship between subjective/self-assessed and objective/actual knowledge. Results suggest that self-ratings of ability generally correlate positively with performance on fact-based tests (e.g., Chezem, Friesen, & Boettcher, 2003; Gossain, Bowman, & Rovner, 1993; Raju, Lonial, & Mangold, 1995) although the relationship is inconsistent (Khan, Awonuga, Dwarakanath, & Taylor, 2001). In this study I built on the work of Denise Schmidt and colleagues (2009) with a self-rated measure of technological pedagogical content knowledge that was individualized to reflect the subject areas taught by each respondent. To clarify the nature of respondents' responses to items such as "I can choose technologies that enhance the [social studies] content for a lesson," I refer to the aggregated measure as TPACK confidence.

Another challenge is to separate out the measure of TPACK from indicators of PCK. Much of the research done on teachers' capacity to use technologies to teach has been with pre-service and novice teachers (e.g., Angeli 2005; Darling-Hammond, Chung, & Frelow, 2002; Schmidt, et al., 2009), smaller groups and case studies of teachers with varying levels of experience (e.g., Hennessy, Ruthven, & Brindley, 2002; Hughes, 2005; Meskill, Mossop, DiAngelo, & Pasquale, 2005; Mishra & Koehler, 2006; Niess, 2005; Snoeyink & Ertmer, 2001/2), and studies that examine large numbers of teachers with a range of experience. These last typically use years of experience as an indicator of expertise (Becker, 2000; Knezek & Christiansen, 2009; Russell, Bebell, O'Dwyer, & O'Connor, 2003; Williams, Coles, Wilson, Richardson, & Tuson, 2000), or occasionally self-report (Archambault & Crippen, 2009). The problem becomes that we know very little about the variability of TPACK among teachers with strong PCK. In this dissertation I explore the measure of TPACK confidence through a survey of accomplished teachers who are independently certified as having high PCK. With this unique data set, I pose the research question, "What is associated with greater confidence in technological pedagogical content knowledge (TPACK)?"

Teaching and Learning Contexts

Having examined what is associated with greater TPACK confidence, I turn my attention to factors that might relate to raising it. Prior studies and theoretical work have identified several important considerations relating to the higher levels of technology use.

Teaching Context

In *The Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators* (2008), several leading scholars give examples of the many ways in which TPACK can be applied. Multiple subject areas are considered, as well as developmental levels ranging from early childhood to adults. In theory, high levels of TPACK are possible in a wide variety of teaching assignments. Yet many factors related to the teaching context such as technology availability, student prior experience, or community expectations may interact with TPACK to produce different observed implementations of technology. Because the teaching context in which the teacher implements the technology may constrain expression of TPACK in various ways, it is important to examine the relationship of these factors to teachers' understandings of technology use in teaching.

Prior Experience

Many argue that experience is critical to the building of new knowledge; the premise that knowledge is constructed through interactive experiences with the world is a foundation of the constructivist and constructionist theories of learning (Ackermann, n.d.; Papert & Harel, 1991). Barron (2004) has shown that students with prior experience with a broader range of technological activities tend to be more confident about their ability to work with and learn about computers than students with less experience. That new learning experiences interact with learners' prior knowledge has been theorized extensively (e.g., Roschelle, 1995). If we begin with the perspective of experience as a necessary condition for the acquisition of knowledge, we might expect TPACK to draw on teachers' prior experiences. The "Technological" added to "Pedagogical Content Knowledge" suggests we consider teachers' experience with technology and with teaching. Studies have shown that both are likely to influence teachers' use of technology in the classroom.

The importance of experience with technology is underscored in several studies. Williams and her colleagues found in a survey of over 600 Scottish teachers that teachers who use computers more frequently at home also report higher use in classroom (Williams, Coles, Wilson, Richardson, & Tuson, 2000). In a case study of three elementary-school teachers in a small Midwestern town, Snoeyink and Ertmer

(2001/2) explore the incentives and barriers faced by three computer novices. The three teachers all reflected on the importance of basic computer skills to their use in instruction. Becker (2000) found in a survey of over 2000 4th- through 12th-grade teachers that high computer knowledge is a factor leading to frequent computer use with students. Zhao and his colleagues (2002), when evaluating the success of projects implemented by grant recipients, noted those teachers with higher levels of technology expertise—beyond proficiency in basic applications—are more able to facilitate the enabling conditions necessary for a particular tool to work. Especially in projects that require more than one component to function, teachers with a broader understanding of computing systems are more successful.

Some believe that younger teachers possess more of those computer skills than older teachers. The idea that younger teachers naturally use more technology in their teaching, which I've often heard voiced in casual conversations, calls for some scrutiny. It is usually presented as an argument against asking veteran teachers to learn new technologies; after all, the large number of teachers soon to retire will naturally lead to a younger, more "techie" teaching force. Even if I were to agree that new teachers come in with stronger TPACK than their experienced colleagues (which I don't), this argument is problematic on at least two fronts. The first is the assumption that a teachers' knowledge of technology use for personal tasks translates into applications in teaching. The second problem with this argument is that new technologies continue to be created. The rate of development of new technologies shows no sign of slowing. Should a large part of the teaching force turn over in the next few years, those new, younger teachers to be hired will soon be challenged to integrate technologies we can't even imagine yet. Even with excellent pre-service education, in which teachers learn to use powerful technologies to support student learning in transformative ways, in-service teachers will need to continue learning.

Several studies support the view that the teacher's experience teaching is even more important than their experience with technology. For example, in a survey of 2,894 teachers in Massachusetts, Russell and his colleagues (2003) looked for patterns in teachers' use of technology. The newer teachers in their study reported higher levels of confidence than more experienced teachers, but novice teachers used technology more for preparation and less for student use than their more-experienced colleagues. The interaction between teaching experience and technology use was also a finding in Hughes's (2005) study. She observed four teachers' technology use and interviewed them about their training histories, and concluded that the teachers brought their teaching experience with them in the form of goals for technology training. Meskill and her team (2002) interviewed novice and experienced teachers about their technology uses, experiences, and beliefs. They conclude that

> …training may not be sufficient for the needed conceptual development that leads to the kind of ease and repertoire characteristic of expert users. Indeed, those novice teachers who had received "state of the art" training in classroom technologies use were far less comfortable in their implementations than the more experienced teacher who had no formal training with computers but a great deal of classroom experience. (p. 54)

All kinds of prior experience can be seen as evidence of knowledge-building activities, and both experiences with teaching and with technology may be helpful in developing TPACK. Teachers who report more use of technology with students, however, may have had the types of experiences most suited to developing TPACK. Therefore measures of all these types of experience were included in the survey.

Learning Ecologies

As the exploration of experience suggests, the different types of technology knowledge identified within TPACK lend themselves to examination from a perspective of the different settings in which teachers develop expertise. The interaction between the various contexts in which teachers learn is highlighted in a "learning ecologies" framework (Figure 2-2). Barron (2004; 2006) defines a learning ecology as "the accessed set of contexts, comprised of configurations of activities, material resources and relationships, found in co-located physical or virtual spaces that provide opportunities for learning" (p. 6). Adolescents have been shown to develop technological expertise across several settings, with lessons learned in one space contributing to activities in another (Mercier, Forssell & Barron, 2008). But knowing how to use a technology is only part of the picture of teachers' technological expertise. TPACK requires knowledge of not only the technological tool, but also its use, affordances, and constraints when applied in the context of supporting student learning in the classroom, which may affect the applicability of the knowledge gained in one setting to another.

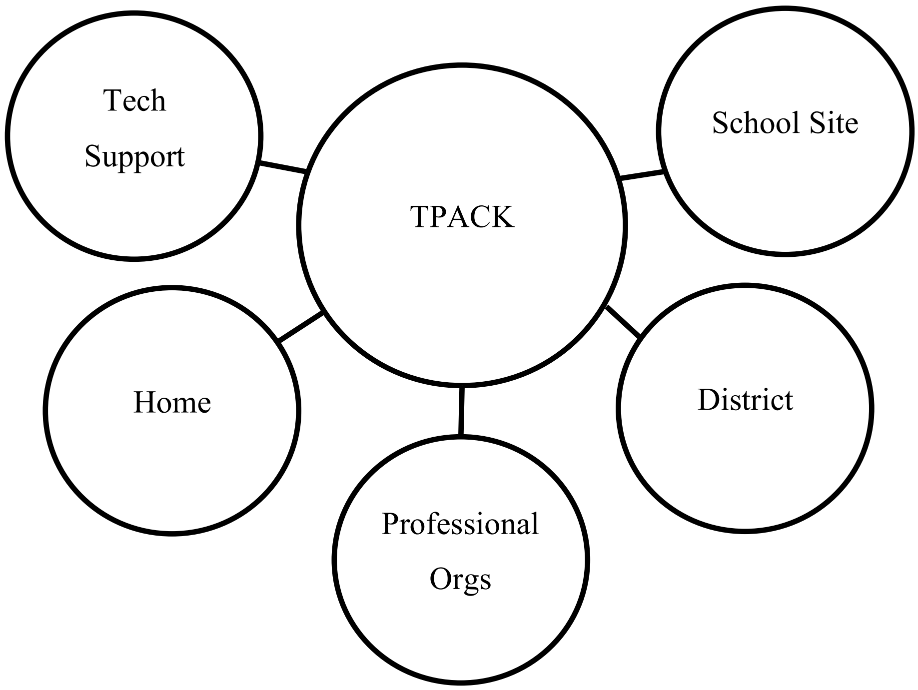

Figure 2-2. The Learning Ecology Conceptual Framework, applied to TPACK. The figure illustrates the different settings that provide opportunities to learn TPACK. Adapted from Barron (2006).

Zhao and Frank take the metaphor of a biological ecosystem and used it as a framework for examining factors affecting technology adoption in schools (2003). They found it productive to use ecologies as a metaphor to talk about the various known cognitive, social, organizational, technological, and psychological factors associated with technology use. One of the reasons that the metaphor works well is that new technology uses are coming in to schools from outside, as "…outsiders, alien species, foreign objects to the environment they entered" (p. 3). The authors' focus was on the movement of ideas for technology use into the school environment; they did not address the movement of teachers from one setting to another. In this dissertation I focus on the teachers as the organisms moving through different environments. A helpful perspective for thinking about the learning that teachers develop in different parts of their lives is situated cognition. The situative perspective extends beyond the individual to recognize the ways in which thinking is influenced by and interacts with the broader context. As Greeno and colleagues explain,

> Success in cognitive functions such as reasoning, remembering, and perceiving is understood as an achievement of a system, with contributions of the individuals who participate, along with tools and artifacts. This means that thinking is situated in a particular context of intentions, social partners, and tools (1996, p. 20).

In applying this perspective to the field of teacher learning, Putnam and Borko (2000) argue that it does not necessarily require that all learning happen where the actions it supports take place. Teacher learning does not always need to take place in the teacher's classroom. They explain, "The question is not whether knowledge and learning are situated, but in what contexts they are situated. For some purposes, in fact, situating learning experiences for teachers outside of the classroom may be important—indeed essential—for powerful learning" (p. 6). They emphasize that researchers need to be attentive to what types of learning best take place in what settings, and how that learning is accessed in other settings. The TPACK framework helps focus this research on the teachers' learning ecologies across settings related to pedagogy (school, district and professional settings), content (discipline-related work environments), and technology (home, community, and online).

What does this perspective suggest about teachers learning to use new technologies for teaching? The definition of TPACK suggests that this specialized knowledge needs to be developed in a context that focuses on the student, classroom, and content to be taught. We would not expect that younger teachers use more technology for their teaching simply because they use more technology in their personal lives. Yet technology knowledge (TK) is part of TPACK; teachers must understand technology use at some level in order to use it in the classroom. Perhaps technology itself is more easily learned in the more relaxed, unstructured private time of a teacher. It can take a great deal of time and focused attention to learn to use a new technological tool; it is important to understand which aspects of TPACK develop in teaching-related contexts, and which might be developed elsewhere. These ecological perspectives suggest that we need to understand how TPACK is supported inside and outside of schools, and how different types of support relate to use of new technologies in the classroom.

Learning Resources

In addition to setting, another critical focus of the learning ecologies perspective is the "material and social resources" available in those spaces. Prior research in technology integration in schools has identified a long list of factors in the classroom, school, and beyond that may be seen as material and institutional resources needed for technology integration to take place (for reviews see for example Hew & Brush, 2006; Mumtaz, 2000). Becker (2000) found in a survey of over 2000 4th- through 12th-grade teachers that teachers who reported frequent use of computers with students tended to have five or more computers in the classroom. Williams and her colleagues (2000) found in a survey of over 600 Scottish teachers that both lack of availability and lack of access were identified by respondents as issues that hindered the use of ICT. Zhao and his colleagues (2002), when evaluating the success of projects implemented by grant recipients, noted that unsuccessful projects were often impacted by lack of access to resources such as computer labs. When Hennessey and her colleagues (2005) conducted focus interviews with Math, English, and Science departments at secondary schools in England, they noted that resources were available to differing degrees in different departments.

Infrastructural support is also needed to use digital technologies. Cuban and colleagues (2001) note in a side comment about their observations and interviews at two high schools, "We heard repeatedly … about inadequate wiring, servers crashing, and constant replacement of obsolete software and machines" (p. 829). The structure of the school day is another aspect of infrastructure; they also report, "The issue of insufficient time was repeated often by faculty" (p. 828). Time within the school day interacts with technology integration on several levels. As Becker (2000) noted in his survey of 2000+ teachers, those who used technology frequently were also more likely to work with students for longer periods of time. Thus elementary school teachers in his study reported more frequent use than secondary school teachers, who typically have a 50-minute block of time in which to teach.

When considering these resources with the lens of technological pedagogical content knowledge (TPACK), the question arises as to which of these resources schools must provide, and which might be accessed elsewhere, such as in teachers' personal lives or online. Perhaps as computers become standard tools for both home use and almost all forms of disciplinary work, teachers will have learning resources outside of schools. Given that computer use in general has increased greatly in the last decade, it is worthwhile to re-examine the role of material resources at school as factors in teacher technology use. To that end I ask, "How do teachers with different TPACK confidence profiles vary in their teaching and learning contexts?"

Social Support for Learning

In addition to material resources, there is increasing recognition of the importance of social resources in support of learning. Support for technology use in schools can take many forms and come from a variety of sources. Many schools and districts provide technology teacher professional development workshops or technology mentors. In addition, Lawson and Comber (1999) identified several support roles in their study of schools in the UK, leading to integrative use of technology. Among these are the role of project coordinator and administrator. These support personnel provided leadership by means of funding, a shared vision, recognition, and incentives for teachers who integrated technology. They argue that an organized program for training both teachers and students, put in place by administration, also contributes to the overall success of the integration. In a case study of three elementary-school teachers in a small Midwestern town, Snoeyink and Ertmer (2001/2) explore the incentives and barriers faced by three computer novices. Central to the context of their study was the fact that "the school board expected faculty to be trained and to make sound educational use of the new equipment" (p. 91). Thus the vision for technology integration came from members of the larger school community.

Zhao and his colleagues (2002), in their examination of factors that relate to more successful project implementation, argue that human infrastructure includes not only flexible and responsive technical staff and a supportive, proactive administrative staff, but also knowledgeable peers who help the teacher understand how to use technologies to fill their needs. Further, they note that social support, the degree to which peers encourage the innovator, is especially important to those projects that depend on others. Williams and her colleagues (2000) note that 80% of the 681 Scottish teachers surveyed reported that they rely on their colleagues for support. The importance of members of the teachers' social network is further demonstrated in a study of the uptake of curricular reforms at two different schools. Penuel and his colleagues found that teachers' connections in the social structure of the school, their social network, related to their perception of the availability of resources (Penuel, Riel, Krause, & Frank, 2009).

The number of members in a teachers' social network is not the only important feature of their learning ecology, however. As demonstrated in Barron's study of parent roles in their children's pursuit of technological fluency, the same person can provide a number of different types of support (Barron, Martin, Takeuchi, & Fithian, 2009). Furthermore, the types of support needed for successful technology integration may be available from different members of the teacher's network than those normally accessed for other types of support (Ryymin, Palonen, & Hakkarainen, 2008). One perspective this relationship between supporter and type of support is to consider the role of social networks in facilitating the acquisition of social capital.

Coleman proposed in 1988 that social capital would be a useful theoretical orientation bringing together two "intellectual streams": the sociologists' focus on the social context as shaping, constraining, and redirecting action; and the economists' focus on the individual's self-interest, which provides the principal for action. Coleman explained, social capital provides an intangible resource that supports productive action:

> If physical capital is wholly tangible, being embodied in observable material form, and human capital is less tangible, being embodied in the skills and knowledge acquired by an individual, social capital is less tangible yet, for it exists in the *relations* among persons. Just as physical capital and human capital facilitate productive activity, social capital does as well. For example, a group within which there is extensive trustworthiness and extensive trust is able to accomplish much more than a comparable group without that trustworthiness and trust. (Coleman, 1988, p. S100-S101, emphasis in original.)

Operating at the boundary between the individual and the social context, this paradigm has since been refined and expanded by several scholars, as Lin reports: "Social capital has gained currency in the social sciences in the past decade as a paradigm to capture the contributions of social elements in explaining a wide variety of individual and collective behaviors." (2004, p. 2). Lin builds on the work of many scholars to argue for a more precise definition of Social Capital "Social capital is the extent of diversity of resources embedded in one's social networks" (p. 4). This perspective's usefulness lies in its suggestion that social networks can provide access to social capital (e.g. information) to develop new human capital, such as knowledge. In considering the learning ecologies of teachers, these theories led me to examine respondents' social networks and their impact on the resources available to support teachers' developing TPACK. Not only the number of people who support teachers' learning (the density of their network) but also the types of support (the diversity of resources) may influence their learning. To explore the idea that teachers' social networks support their learning I ask, "What is the nature of the relationship between teachers' TPACK confidence and the learning support they access through their learning networks, across settings in their learning ecologies?"

Pilot studies

Five exploratory studies have examined the relationships between parts of this framework. The data were collected through online surveys administered in the context of either input gathered to inform a school technology plan, or summer technology professional development workshops in two districts. These pilots confirmed the importance of attending to the factors identified above in the context of teachers' developing TPACK, and refined the research questions for this study.

Technology Use & Experience

Thirteen K-12 teachers attending a district-sponsored summer technology workshop reported on their teaching and computer experience, attitudes, and use of technology with students (Forssell, 2009c). The number of different types of computer activities engaged in for three types of tasks – personal use, teacher productivity, and teaching students – were used to examine the characteristics of teachers reporting high levels of expertise in using technology for teaching. Analyses of the relationship between technological expertise and years of teaching experience revealed three different teacher profiles, suggesting that both teaching and technology background play a role in technology use for teaching. Levels of computer use for teacher productivity were largely similar among the three profiles, while use with students differed. Veteran teachers with high self-reported technology expertise showed the greatest breadth of computer activities with students. This study highlighted the importance of including breadth of activities as a measure of student computer use, and raised questions about how to measure teaching experience, i.e., are we interested in age or in expertise in teaching, and to what degree are they related? This lead to a focus on accomplished teachers in the current study.

TPACK, Social Resources, & Learning Ecologies

Participants in a summer technology workshop completed an online survey of their self-rated skill in using technology for teaching, general confidence using new technologies, learning supporters, and computer use with students (Forssell, 2009a). The importance of learning supporters was examined through participants' ratings of "How important have the following people been in your learning how to use digital technologies?" for 11 different relationships. An exploratory factor analysis indicated that in this sample, the relationships fell into four categories: the family, the school, the administrator, and "significant peers." This last category, comprised of friend, spouse/significant other, and outside colleague, was a critical source of learning for teachers with high levels of technology confidence, self-rated skill using digital technologies for teaching tasks, and a range of software use with students. Specifically, teachers who rated a spouse/significant other as an important learning supporter also reported higher technology confidence and a broader range of computer-based activities with students. Technology confidence and skill using technology for teaching tended to be high for those participants who said that an outside colleague was important to their learning about technology. There was no relationship between breadth of activities with students and in-school learning supporters. This study supported the importance of studying learning supporters across various settings, while also pointing out possible gaps in the list of relationships, specifically those that might be "significant peers" outside the worksite.

Another pilot study explored the relationship between teachers' learning support networks and TPACK in an online survey (Forssell, 2009b; 2010). Forty-five middle-school teachers in a summer workshop were asked "Please list up to 5 people (fewer is fine) who support your learning about digital technologies for your work as a teacher. Think about people inside and outside of school, teachers and non-teachers." Participants then reported the types of support received from each person, as well as their relationship to the participant. The number of supporters, number of roles filled, and relationships were analyzed together with measures of self-reported TPACK. Results suggested that although having more supporters of technology learning was advantageous, the more important factor was the types of support available to teachers to support their learning about technologies for teaching. Specific kinds of support are associated with reports of higher TPACK. Teachers with high TPACK were significantly more likely to report that someone lent them resources such as books, funded their technology, or paid them to learn about technology. Furthermore, the number of subject area colleagues nominated as important supporters by high TPACK teachers was significantly higher than for teachers reporting low TPACK.

The importance of subject-area colleagues was further confirmed in an unpublished study conducted in the fall of 2009, in which 53 teachers were asked to reflect on successful and unsuccessful uses of digital technologies with their students. A pattern emerged in which teachers often found out about the successful technologies from fellow teachers, especially in their own department. The unsuccessful attempts were often prompted by interactions with people who were not teachers, and very rarely by subject-area colleagues. These results pushed me to think about the types of support provided by individuals in different settings, using the learning ecology framework with a focus on settings relevant to the domains in the TPACK framework.

The literature provided many suggestions as to what the nature of TPACK might be, and how it might relate to various factors in the teaching and learning contexts of participants. In the designing this study, I drew on these findings and theories from the literature to identify important measures relating to teachers' understanding of how to use new technologies to support student learning. Drawing on the TPACK and learning ecology frameworks, I explored relationships across settings and in relation to technology, pedagogy, and content. I tested measures and preliminary research questions through pilot studies. The resulting study is described in the following chapter.

CHAPTER 3: METHODS

This study uses data from an online survey of National Board Certified Teachers in California to examine teachers' confidence in their technological pedagogical content knowledge (TPACK) and its relationship to teaching and learning contexts, with special focus on the relationships in their social networks that support their learning to use new technologies for teaching.

Participants

An invitation to participate in an online survey was sent to e-mail addresses for 2,717 National Board Certified Teachers (NBCTs) certified in California in the years 2000 through 2008. A NBCT support program provided me with a list of 3,827 NBCTs certified 2000-2008 in California, of whom 2,716 had provided their e-mail address. My own e-mail address was on the list, but I counted myself as a non-respondent. The results of the 2009 National Board entries were announced in December 2009, during data collection. One of the participants in my study referred me to a 2009 NBCT, to whom I sent an invitation to participate. I did not have e-mail addresses for the other 2009 NBCTs.

The 566 respondents who started the survey represent 20.8% of the e-mail addresses available, and 13.4% of the total population of 4,226 teachers who achieved National Board Certification in California in that time period. Given that this is a small percentage of the total population, the next chapter will be dedicated to examining the characteristics of the participants, to determine possible sources of bias in this sample.

Of the 566 participants in the survey, 421 (74.4%) reported that they currently taught at least part time in the classroom. Those no longer teaching ranged in their current pursuits; common transitions include retiring from teaching, moving into school administration, pursuing advanced degrees in education, working as a teacher coach or content area specialist, or caring for family members.

Of the 421 currently teaching, 307 completed the section of the survey from which their confidence in their ability to use technology for teaching was derived, which forms the focus of this study. This study is limited to those 307 teachers, of whom 81% were female and 19% male. They ranged in age from 30 to 66 (M = 48.9, SD = 9.1). Participants reported their race/ethnicity as: White/Caucasian (77.7%), Hispanic (13.1%), Asian (4.6%), Black/African American (2.0%), Native American (1.3%), Pacific Islander (1.0%), and Other (3.3%). Fifty-one respondents in this study chose not to report what year they were born, 3 did not report their race, and 4 chose not to respond to the question of gender.

Experience

A minimum of three full years of teaching experience is required for National Board certification. Teachers in this study had been in the classroom anywhere from 6 to 46 years, with an average of over 18 years of experience (M = 19.2, SD = 7.9). They represented a wide range of teaching assignments, including Pre-K (2), Primary (75), Upper Elementary (83), Middle (60), and High School (111). Eleven respondents reported that they taught at the post-secondary level, taught teachers, or provided instructional or curricular support to teachers. Of these 11, all but 4 also taught K-12 students. Twenty-five respondents reported teaching assignments that spanned more than one of these 6 levels.

Teaching Assignments

Many participants reported that they currently taught multiple subjects. Because this is especially common at the elementary level, it is helpful to distinguish between elementary and secondary teachers when examining differences by subject area taught. For the purposes of these descriptions, any participants who reported that their lowest teaching assignment was at or below grade 5 were coded as elementary teachers.

Among elementary teachers (n = 134), 88.8% taught English/Language Arts, 82.8% taught Math, 77.6% taught Science, and 75.4% taught Social Studies. Among secondary teachers (n = 169), 32.0% taught English/Language Arts, 20.1% taught Math, 19.5% taught Science, and 14.2% taught Social Studies.

Table 3-1 gives an overview of the expertise represented by National Board Certification Specialties. Although all respondents earned National Board certification in California, not all taught there still at the time of the survey; three reported in the comments or e-mail to the researcher that they now taught in other states or countries. These certifications were provided with the original list used to recruit NBCTs for this study. Where the respondent indicated a different certification, the respondent's choice was considered most accurate. Because the survey was first sent anonymously, it was not possible to match two of the respondents to their certificate areas.

Table 3-1. Participant teaching expertise by National Board Certificate

Certificate		*N*	%
Early Childhood Generalist		53	17.3
Middle Childhood Generalist		40	13.0
Early and Middle Childhood			
	Art	2	0.7
	English as a New Language	13	4.2
	Literacy: Reading-Language Arts	15	4.9
	Music	2	0.7
	Physical Education	3	1.0
Early Adolescence			
	Generalist	2	0.7
	English Language Arts	13	4.2
	Mathematics	12	3.9
	Science	10	3.3
	Social Studies - History	6	2.0
Early Adolescence through Young Adulthood			
	Art	7	2.3
	Career and Technical Education	3	1.0
	English as a New Language	5	1.6
	Music	2	0.7
	Physical Education	8	2.6
	World Languages Other than English	9	2.9
Adolescence through Young Adulthood			
	English Language Arts	34	11.1
	Mathematics	12	3.9
	Science	18	5.9
	Social Studies - History	10	3.3
Early Childhood through Young Adulthood			
	Exceptional Needs Specialist	20	6.5
	Library Media	8	2.6
Unknown		2	0.7

Teaching Context

Participants taught in a variety of school contexts. These categories were not defined in the survey, but were left for participants to interpret. The respondents taught in a variety of neighborhoods: Inner City (23.1%), Urban (31.9%), Suburban (33.9%), Small Town (6.5%), Rural (2.9%), and Other (1.3%). The majority described the school in which they teach as Public (88.3%), with the rest describing their school as

Magnet (3.9%), Charter (3.9%), Private (1.3%), or Other (1.3%). Almost two out of three participants in this study (63.6%) worked in Title 1 schools, in which at least 40% of the students qualify for free or reduced lunch. On average, respondents estimated that 60.6% (*SD* = 31.3%) of the community served by their school was low-income. Over one quarter of the respondents (26.9%) worked in schools recognized as a successful school (Distinguished / Blue Ribbon / AAA), while 41.6% reported that their school was receiving assistance to improve student achievement (Program Improvement / State Monitored / High Priority).

When asked to describe the courses they teach, 28.7% of participants reported that they taught courses for advanced students (AP / IB / Pre-IB / Honors / GATE), while 14.9% taught remedial courses. Thirty-five percent taught courses designated for English language learners. Almost one respondent in seven (13.9%) taught special education courses, and 81.5% taught regular education courses. Participants were instructed, "This question is about your courses, not the students. For example, if you teach a regular education course with some ELL students, check regular education." Because one teacher may teach several types of courses, these numbers add up to more than 100%.

Technology

In order to encourage a wide range of teachers to participate, respondents were given the option of completing the survey on paper, and every effort was made to encourage participation from teachers who do not to use technology in the classroom through the language of the invitation e-mails and the survey items. No respondents requested paper copies.

The average number of working computers for student use in the classrooms of participating teachers was 7.24 (*SD* = 11.4). When analyzing the data, it became apparent that respondents interpreted this item differently. Some appear to have counted computers as both "available for checkout" and "available in classroom," especially in the case of mobile computers. Because the computers were considered "available" to the respondents, they were included in this analysis, but the range was capped at 40 computers. Several respondents also commented that though available, their computers were not powerful. The distribution was positively skewed with high kurtosis, as illustrated in Figure 3-1 below; 29.6% of the participants reported having no computers in the classroom and 8.5% reported that no computers were available for them to use with students at their school. Of those who did have at least one computer in the classroom, the modal number of computers was 1, with a median of 4.

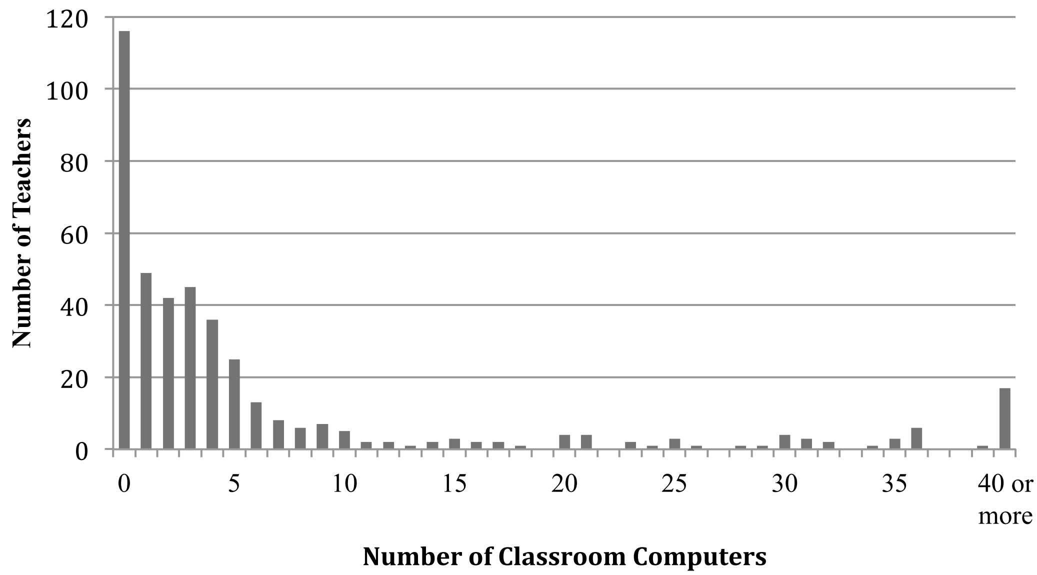

Figure 3-1. Frequency of number of total computers for student use in the classroom. On the y-axis is the number of teachers who reported that number of computers "in the classroom or where you teach."

Procedures

An invitation to participate in an online survey was sent to e-mail addresses for 2,717 National Board Certified Teachers (NBCTs) certified in California in the years 2000 through 2008. The invitation asked NBCTs to participate in a Stanford research study of "how accomplished teachers decide whether to use new technologies with students." The director of a National Board certification support program sent the first invitation, with a link to an anonymous survey, in November 2009. Technical issues and time constraints resulted in a limited number of invitations being sent, and 25 responses were initiated. New invitations were sent in December using the survey distribution tool in the Qualtrics online survey tool, which personalized the e-mail with the participant's first name, and included a personalized link to the survey for each participant. This tool also allowed reminder e-mails to be sent to potential participants who had not yet completed the survey. Up to three reminders were sent through the end of January 2010, to encourage completion of the survey.

The survey was designed to take between 30 and 45 minutes to complete. NBCTs who indicated that they no longer taught at least part time in the classroom did not receive those questions related to current access and usage, resulting in a much shorter survey. Those teachers who taught multiple subjects had a longer survey than those who taught fewer subjects, because parts of the survey were sensitive to the subjects participants taught. For example, a teacher who taught science received questions about knowledge and beliefs about technology for teaching science, while a teacher teaching four or five subjects received a set of similar questions for each subject. Respondents were able to leave the survey before finishing, with the answers being saved, and could return to the survey any time within two weeks of starting to complete it. Responses to questions were optional, so the number of data points in the analyses below will vary based on whether the participants chose to answer the questions. After the survey was closed, all personally identifying information was removed from the data for analysis.

In February 2010, a second solicitation was sent to determine whether the respondents differed from the non-respondents on three dimensions: teaching experience, frequency of technology use for teaching, and beliefs about the value of technology for students' academic achievement. The short follow-up survey included the three questions and a link to the online survey. The e-mail was sent to the respondents who had indicated they are currently teaching ($N = 418$), of whom 256 responded. Because first invitation to the original survey was sent with an anonymous link, there were three current teachers who could not be matched for the follow-up e-mail. There were 25 responses (of which 13 were complete) to the initial invitation; subsequent invitations were sent using the direct mailing option in the Qualtrics online survey tool, which allowed follow-up e-mails to be sent to participants with particular response profiles. After the survey was closed, all personally identifying information was removed from the data for analysis.

Measures

The survey consisted of questions about the participant's confidence using technology in and out of the teaching context; experience using technological production activities in personal and student contexts; social and material learning resources in school and offsite; beliefs about the value of technology in schools and in society; information about the participant's teaching context and access to technologies; and individual demographics. Table 3-2 presents the sections of the survey, the constructs measured, and the number of items. A table of all measures and the Chapter in which they were used is available in Appendix A. The full survey is included in Appendix B.

Table 3-2. Description of survey sections and constructs

Section	Measures	Number of items	Survey
Confidence	TK	7	Main
	TPK	5	Main
	TPACK	5 / subject	Main
	PCK	1 / subject	Main
	TCK	1 / subject	Main
Knowledge	Familiarity with terms	27	Main
Experience	Years teaching	1	Main
	Production Activities (personal)	16	Main
	Production Activities (students)	16	Main
	Personal use	6	Main
	Frequency of use for teaching	2	Follow-up
Resources	Available equipment (school, class)	31	Main
	Available / important learning resources (in school or district / outside)	20	Main
Social Resources	Learning supporters named	Up to 16	Main
	Roles filled	Up to 9 each	Main
	Relationships	1 each	Main
Beliefs	Technology	6	Main
	Technology & Pedagogy	14	Main
	Technology & Pedagogy	1	Follow-up
	Technology & Content	4 / subject	Main
	Technology, Pedagogy & Content	8 / subject	Main
Teaching Context	Community, school, courses	7	Main
Demographics	Age, gender, race/ethnicity, education level	4	Main

TPACK

A survey designed to assess pre-service teachers' TPACK (Schmidt, et al., 2009) was modified to address in-service teachers. The original survey was validated through expert review, followed by sub-scale validity and construct validity analyses (Schmidt, et al., 2009). Teachers responded on a 5-point scale from Strongly Disagree (1) to Strongly Agree (5) to statements such as "I can select technologies to use in my classroom that enhance what I teach and what students learn." As self-report items, these measure respondents' confidence in their TPACK; they do not measure actual knowledge. The full survey includes sections relating to pre-service teacher education; I modified the items relating to TK (7 items), TPK (5 items), and TPACK (5 items) to make them applicable to in-service teachers.

Table 3-3 presents examples and reliability measures for these constructs. Principal component analysis showed that each scale loads on one eigenvalue. In addition I included the two single PCK and TCK items from the original survey.

Table 3-3. Constructs related to TPACK confidence

Construct	Example item	Reliability
Technological Knowledge (TK) Confidence	*I know about a lot of different technologies*	Scale (7 items) Cronbach's α=.92 PC1 explains 68%
Technological Pedagogical Knowledge (TPK) Confidence	*I can adapt the use of the technologies that I learn about to different teaching activities.*	Scale (5 items) Cronbach's α=.90 PC1 explains 72%
Technological Pedagogical Content Knowledge (TPACK) Confidence	*I can choose technologies that enhance the [math] content for a lesson.*	Scale (5 items) Cronbach's α=.94 to .96 depending on subject. PC1 explains 88 to 91%
Technological Content Knowledge (TCK) Confidence	*I know about technologies that I can use for understanding and doing [mathematics].*	1 item
Pedagogical Content Knowledge (PCK) Confidence	*I know how to select effective teaching approaches to guide student thinking and learning in [mathematics].*	1 item

Through rules built into the online survey, all items relating to content reflected the subject area(s) taught by the teacher. I followed the example of the original survey designers, averaging multiple items to give scale scores.

To measure participant's technological knowledge, I used a survey instrument (Hargittai, 2005) on which participants rated their familiarity with 27 Internet-related terms from none (1) to full (5). This instrument was validated through observations of participants' actual Internet-browsing behavior. The mean scores were computed for each participant (missing items were replaced with the mean).

Experience

Classroom teaching experience. Teachers were asked how many years they have been in the classroom. Given that many teachers either start teaching without a credential, or take a leave (for example to raise children), this may be different from the number of years since they earned their credential.

Experience using technology. To look at teachers' prior experience with technology in the classroom, I built on measures developed by Barron (2004; 2006). The 16 production activities relate to creativity and innovation, collaboration and communication, or critical thinking and problem solving. Examples include making a movie, starting an online discussion, or using a simulation to model a real life situation. Participants were told "The following set of items asks about your experiences with technology in and outside the classroom. We'd like to know how many times you yourself have created the following types of products, and how many times you have asked students to do these activities in your class(es)." In side-by-side matrices, participants were asked to indicate the number of times 1) they and 2) their students had ever engaged in each activity from a choice of: never, 1-2 times, 3-6 times, and 7+ times. These provided measures for both technology use with students and technology use for personal tasks.

Use in Teaching

Frequency of use with students. A measure of frequency of computer use with students was included in the follow-up survey sent to the respondents who had indicated they are currently teaching. Participants were asked "On average, how often do you plan for a typical student to use a computer during class?"

Internet use for teaching ideas. A measure of the frequency with which respondents get inspiration for teaching online was included in the follow-up survey sent to the respondents who had indicated they are currently teaching. Based on item in the MetLife Survey of the American Teacher (Markow & Cooper, 2008), participants were asked "How often have you used an Internet resource to get teaching ideas?"

Personal Use

A measure of teachers' personal computer use was generated from 6 survey items. The items asked participants how often they used computers and/or the Internet for the following personal tasks: read or send e-mail; learn information about a topic that is of personal interest; talk to others online about a hobby; play games; work on digital media projects; edit a blog or social networking page.

Resources

Equipment. Teachers were asked to indicate from checklists which types of technology they had available to them in their classroom and elsewhere in their school. Included in these lists were the numbers of desktop and laptop computers.

Learning resources. Teachers were asked to choose from a list the resources such as workshops, publications, or online networks *available* to support their learning in the school or district. Later, teachers indicated which resources inside and outside of the school or district were *important* to their learning to use technologies in school.

Social resources. Survey participants were asked to list important people who supported their learning of technology for teaching. Participants indicated the nature of the support each learning supporter provides, and the supporter's relationship to the participant.

Beliefs

Using the TPACK model as a framework, I created a series of scales to examine respondents' beliefs about technology (T), technology in teaching and learning (technology and pedagogy, TP), technology in the discipline taught (technology and content, TC), and the use of technology to support student learning of a particular subject or topic (TPC). These items combined statements from previous studies with new items. Prior surveys of teachers' attitudes toward technology used for this study included the Teachers' Attitudes Toward Computers Questionnaire (TAT) developed by Rhonda Christensen and Gerald Knezek in the mid-1990's and used extensively since then (Christensen & Knezek, 2009); Hank Becker's Teaching Learning, and Computing: 1998 (TLC) A National Survey of Schools and Teachers Describing Their Best Practices, Teaching Philosophies, and Uses of Technology (Becker, 2000); and the USEiT Teacher Survey from the Use, Support, and Effect of Instructional Technology Study (Higgins & Russell, 2003). All of these surveys built on previous surveys in the field, in an attempt to understand the reasons why teachers would choose to use or not to use computers in the classroom.

When necessary, existing items were modified to fit the constraints of this survey, namely: 1) all items are statements of technology's potential, not teacher confidence or ability, 2) statements about specific technologies (e.g., computers or e-mail) are changed to refer to "technology/technologies," which is defined often throughout the survey, and again above these items, 3) statements relate to the potential for technology to increase the ability to meet a goal.

Approximately half the items in each scale reflect a belief conflicting with the use of technology, because "offering respondents a second substantive alternative on an issue will significantly decrease the percentage of respondents endorsing the first alternative from a single-sided form" (Bishop, Oldendick, & Tuchfarber, 1982). In order to further counteract the possible inference that the "pro-technology" belief statements are more socially acceptable, participants were asked to rate the items on a 5-point scale from (1) Strongly Disagree to (5) Strongly Agree. The positioning of "disagree" closer to the statement than "agree" may help to differentiate the responses. A "neither agree nor disagree" option provides additional reliability (Presser & Schuman, 1980).

The items in each scale were presented together in the survey. This raised the likelihood of the items being treated by the participants as related to an underlying construct by forming a response set. To discourage order effects, the survey software was set to present beliefs in random order within each subscale.

Table 3-4. Technology beliefs measures

Construct	Example item	Reliability
Technology (T) Beliefs	*Technology is changing the world too rapidly. (Christensen & Knezek, 2009)*	Scale (6 items) Cronbach's α=.69
Technology in Discipline (TC) Beliefs	*New types of work in [the discipline I teach] have been made possible by technology.*	Scale (4 items) Cronbach's α=.59 to .80 depending on subject
Technology & Pedagogy (TP) Beliefs	*When using technology, students take more initiative outside of class time—doing extra research or polishing their work. (Becker, 2000)*	Scale (14 items) Cronbach's α=.70
Technology, Pedagogy, & Content (TPC) Beliefs	*Technology helps students grasp difficult [subject] concepts more easily. (Russell, Bebell, O'Dwyer, & O'Connor, 2003)*	Scale (8 items) Cronbach's α=.84 to .89 depending on subject

Through rules built into the online survey, all items relating to disciplinary content reflected the subject area(s) taught by the teacher. Multiple items were averaged to give scale scores. Table 3-4 presents examples and reliability measures for these constructs.

Technology beliefs. Koehler and Mishra (2008) describe their idea of Technology Knowledge as being derived from the NRC's (1999) definition of fluency of information technology (FITness), which suggests that this type of fluency "enables a person to accomplish a variety of different tasks," and "develop different ways of accomplishing a given task" (p. 15). I included these as belief statements. In addition, I used several items from a survey of Teachers' Attitudes toward Technology (Christensen & Knezek, 2009), looking specifically for statements reflecting beliefs about the role of technology in individual as well as interpersonal activities.

Technology-pedagogy beliefs. The Technological Pedagogical Knowledge (TPK) construct has been described as "an understanding of how teaching and learning changes when particular technologies are used" (Koehler & Mishra, 2008, p. 16). Several published questionnaires (Becker, 2000; Christensen & Knezek, 2009; Higgins & Russell, 2003; Williams, et al., 2000), have addressed teachers' perceptions of how technology relates to students' learning, engagement, interest, motivation, effort, and work quality. These items are relevant to the question of how technology can influence teaching and learning. In addition, strong TPK includes "an understanding that technology can also be misused and that each technology has limitations" (Cox, 2008 p. 41). Previous surveys include items measuring teachers' agreement with statements of negative consequences of technology integration. I have sought to balance the belief scales by including such negative items.

Technology-content beliefs. To create the items relating to beliefs about the value of technology in the discipline, I turned to the descriptions of TPACK constructs in the literature. I build on the work of Suzy Cox, who gathered an extensive list definitions and examples of TPACK from the literature, and consulted experts in the field to help clarify the boundaries (Cox, 2008). The items in the beliefs scales address the themes arising from her analyses. In addition, I contribute an item related to the practices of professionals in the discipline. This is in response to the oft-cited rationale that students need to learn to use technology in order to prepare them for future jobs, and the similar preparatory rationale for schooling.

Technology-pedagogy-content beliefs. To measure beliefs relevant to teaching content with technology, I built on descriptions of TPACK, as well as of PCK. Although there has been a great deal of discussion about the nature of PCK, and there is no one accepted definition, the following five key elements (Magnusson, Krajcik, & Borko, 1999) are commonly cited: orientations toward [subject] teaching, knowledge and beliefs about [subject] curriculum, knowledge and beliefs about students' understanding of specific [subject] topics, knowledge and beliefs about assessment in [subject], and knowledge and beliefs about instructional strategies for teaching [subject]. I used these as a starting point to generate statements about the usefulness of technology to address PCK-related elements. As with the other constructs within the beliefs section, up to half of these items reflect a negative view of technology.

Teaching Context

Participants indicated the grades and subjects they are currently teaching. In addition, information was gathered about the community (Inner City, Urban, Suburban, Small Town, Rural), school (Public, Private, Magnet, Charter, Honors or Assistance from the state, Percent low-income, Title 1), and courses taught (AP / IB / Pre-IB / Honors / GATE, Remedial, Special Education, English Language Learners, Regular Education).

Demographics

In addition to the measures above, I collected demographic data relating to participants' age, gender, race/ethnicity, and education.

Chapter 4: Characteristics of Respondents

In a survey study it is important to know the response rate, because it helps us to gauge the generalizability of the findings to the larger population. In this dissertation study, the response rate was too low to generalize the results beyond the sample. Nevertheless the findings are instructive, as they contribute to our understanding of TPACK confidence. In this chapter I describe the response rate, response bias, and representativeness of the sample on several dimensions that may be salient to the findings.

Organization of the Chapter

This chapter is divided into three parts. Part 1 addresses the response rate by identifying the issues related to performing the calculation, then providing an argument for interpreting the response rate as anywhere from 18% to 25%. Part 2 addresses the question of response bias. Potential bias is explored due to the online survey format and the topic of technology in teaching. Part 3 examines representativeness of the sample based on comparisons of demographic variables to non-respondents, teachers in California, and teachers in the United States.

Methods and measures are explained as part of each set of analyses. Each part of this chapter ends with a summary of findings and their implications. A discussion of the findings across all analyses concludes the chapter.

Part 1: Response Rate

There is no hard and fast rule for what minimum response rate is acceptable; scholars have argued for anywhere from 50% to 80% (Baruch & Holtom, 2008). An analysis of surveys published in respected journals show average response rates of 52.7% (Baruch & Holtom, 2008), with a standard deviation of 21.2%; much lower response rates have been considered acceptable for publication. In the field of education, one example of a published study with a relatively low response rate is by Darling-Hammond, Chung, & Frelow (2002). The article reports a response rate of 33% in a study of novice teachers in New York. In calculating this figure, the authors detracted approximately 4,000 (20%) surveys from the original 20,000, which were returned undelivered, and an additional 7,000 (35%) based on estimates of teachers leaving the teaching profession. The 2,956 usable surveys were compared to a final denominator of 9,000 for a response rate of 1 in 3. This example is instructive in highlighting the issues of survey delivery and teacher mobility.

Between 2000 and 2008, 4,226 teachers received National Board Certification in California. Of those, 2,717 had provided their e-mail addresses to a support organization, which provided the list for the current study (for more about those addresses, see Chapter 3). The availability of e-mail addresses was largely a function of time; the teachers certified in 2004-2008 were more likely to have an e-mail address on the list (96.4%) than their colleagues certified 2000-2003 (54.4%). Of the e-mails sent, two were returned with an "undeliverable" message. One recipient responded to say that he was not the intended adressee. A total of 566 individuals visited the first page of the survey, representing 20.8% of the 2,714 remaining adresses.

However using 2,714 as the denominator of the calculated response rate is potentially misleading. I don't know how many of the 2,714 received the invitation to participate; my own e-mail address was listed in an outdated format, and I never received the invitation to participate. Further, using 566 for the numerator is inappropriate, as the focus of the current study is on the 307 current teachers who completed the survey items relating to technological pedagogical content knowledge. I do not know how many of the 2,714 were currently teaching. Following the example of the novice teacher study, it is appropriate to revise the denominator to reflect these considerations.

Delivery

Potential reasons for not receiving the e-mail include abandoning a personal e-mail address, a change in the school or district's domain name, and leaving the school or district. A study of teacher mobility suggests that in the years 2000-2009, anywhere from 7.6 to 8.1% of public school teachers moved to another school, and 7.4 to 8.4% left the profession entirely each year (Keigher, 2010). Although we have no good estimate of the number of invitations to participate that reached their intended recipient, an analogy with the study of novice teachers cited above in which 20% of the invitations were returned undelivered, suggests that 544 of the potential respondents may not have received the invitation to participate.

Teacher Mobility

In addition to affecting the delivery rate, teacher mobility also impacts the number of qualified responses. The focus of this study is on NBCTs who are currently teaching, and so an estimate of how many of the 2,714 intended recipients were current teachers would help to determine the response rate. There is evidence that NBCTs are more likely than their colleagues to move on to other challenges: "successful applicants (certified teachers) at the early and mid-career levels are more likely than the applicant group as a whole to leave their school or the state" (Goldhaber & Hansen, 2009 p. 239). To estimate how many of the invitees were current classroom teachers, I turned to the received survey responses. Of the 566 individuals who started the survey, 506 reported whether they were currently teaching in the classroom at least part time. This question was required, and so anyone who did not answer it did not continue with the survey beyond this point. Current teachers made up 83% of those who answered the question. Extending that ratio to the entire potential address list suggests that at least 462 of the 2,714 were no longer teaching in the classroom. Judging by the fact that the majority of the correspondence I received from potential respondents involved questions or statements relating to the fact that they were no longer teaching, this is most likely a conservative estimate.

There is additional evidence that some combination of address abandonment and teacher mobility may have impacted the potential response base. More recently certified NBCTs responded to the survey at a significantly higher rate than teachers certified earlier, with 21.2% of respondents certified from 2005 to 2008 visiting the first page of the survey, as compared to 11.3% of teachers certified between 2000 and 2004 ($\chi^2(1, N = 2717) = 48.95, p < .01$). This may be a function of more accurate e-mail addresses, of other factors such as NBCTs leaving the profession, or of shifts in characteristics of teachers who chose to become certified. As an example of the differences across years, a 2001 paper survey of all the 786 teachers who had then been certified by the NBPTS in California resulted in a 68% return rate (Belden, 2002). It may be relevant that many of the financial incentives for NB certification from the state of California were discontinued in 2003, resulting in fewer teachers pursuing certification. Figure 4-1 presents a visualization of the percentage of respondents as compared to the potential response bases.

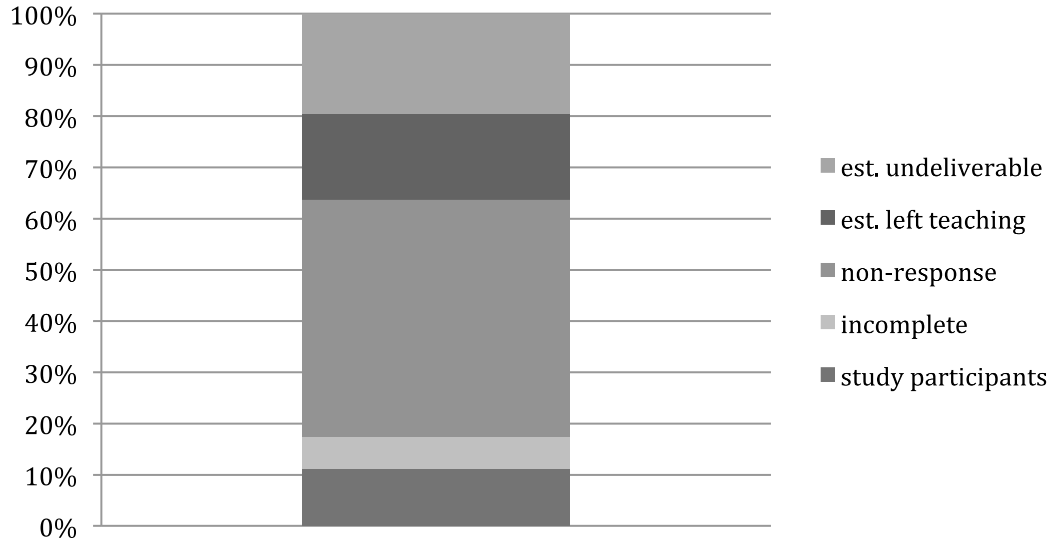

Figure 4-1. Responses to the survey as proportion of 2,717 National Board Certified Teachers (NBCTs) in California 2000-2008 with e-mail address on list.

Survey Completion

In addition to the denominator, the numerator for calculating the response rate is debatable. As shown in Figure 4-2, the number of participants who completed the entire survey is approximately 75% of those who completed the question indicating that they currently taught in the classroom. Furthermore throughout the survey, participants could opt to pass a set of questions without responding to them. Thus when calculating the response rate, the ratio would change depending on the criterion for the numerator. Although 421 participants indicated that they currently taught in the classroom, only the 307 who completed the items rating their confidence in their technological pedagogical content knowledge were included in the current study.

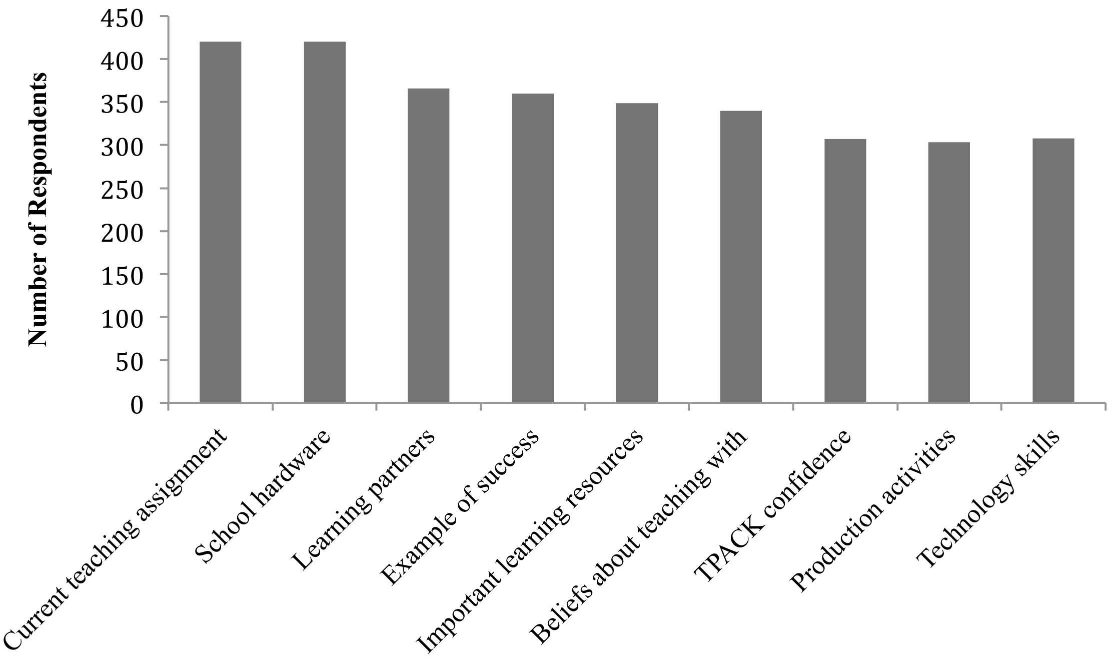

Figure 4-2. Breakdown of responses by current teachers to sections in survey. Responses were optional, which allowed respondents to skip questions when they wished.

Summary: Response Rate

Individuals who answered at least one question in the survey represent 20.8% of all *potential* participants (566 of 2,717). If I assume that 20% of the invitations went to e-mail addresses that were no longer monitored, and that an additional 17% of those on the invitation list were no longer teaching, the response rate was 24.6% (421 of 1,711). The 307 respondents who completed the measures assessing their own technological pedagogical content knowledge (TPACK) represented 17.9% of this estimated deliverable list.

By any of the calculations, the response rate for this survey was low. The study includes only those NBCTs who 1) provided an e-mail address to the support organization, 2) received the e-mail inviting them to participate, 3) chose to respond to an online survey of technology use in teaching, 4) were currently teaching, and 5) completed the survey items related to TPACK confidence. This raises the question of whether the 307 respondents tended to represent a particular point of view due to the survey format or topic. Part 2 of this chapter addresses the response bias by comparing respondents to non-respondents and to other teaching populations.

Part 2: Response Bias

Response rates are important because they suggest how representative the sample may be of the population. The concern, however, is not the percentage per se; the concern is that the likelihood that the respondents may be biased in some way. The risk of bias is higher when only a small portion of the population responds. To answer the question whether results were biased based on who chose to participate in the study, I compared the respondents to this survey to non-respondents and to Californian and US teachers. There are several types of non-respondents identified in the literature (Bosnjak & Tuten, 2001), including those who chose not to respond because of the online format, or because they were not interested in the topic, as opposed to those who would not have responded under any condition. The focus of this analysis is to identify variables that might suggest a response bias due to the online format and topic.

Survey Format

The online format may have impacted response rates, as studies have shown that online surveys tend to have 11% fewer respondents (Manfreda, Bosnjak, Berzelak, Haas, & Vehovar, 2008). For that reason, respondents were given the option of completing the survey on paper, and inclusive language in both the invitation e-mail and the survey items encouraged participation from teachers who do not use technology. No invitees requested paper copies.

Studies also suggest that respondents to online surveys are younger and more technologically inclined than respondents to paper-based surveys, but these differences are inconsistent and may be disappearing (Andrews, Nonnecke, & Preece, 2003; Sax, Gilmartin, & Bryant, 2003). This may be a concern because NBCTs tend to be mature teachers, and thus older than the general teaching population (Belden, 2002); the risk is that the perspective of older teachers would not be adequately represented. On average respondents in this study were 6 years older (M = 48.8, SD = 9.1) than US teachers (M = 42.8 per Scholastic, 2010). A higher percentage of respondents were in the higher age ranges than US (Scholastic, 2010) and Californian (CDE, 2009) teachers. The percentages of teachers in the sample and in comparison populations are presented in table 4-1.

Table 4-1. Age of respondents and of comparison teachers.

	Respondents	Californian teachers	US teachers
>55	25.4%	21.5%	
≥50	47.7%		34%
46-55	32.0%	24.5%	
35-49	40.6%		36%
<46	42.6%	53.8%	
<35	11.7%		29%

Survey Topic

Individuals who are interested in the subject of a survey are more likely to respond to it (Andrews, Nonnecke, & Preece, 2003), so a major concern in this study was that respondents may have used technology more often in support of teaching, and believe that technology is more beneficial to students, than non-respondents.

In order to determine whether the participants who responded differed from the invitees who did not, I sent a follow-up invitation asking for participation in a short survey of their teaching experience, frequency of technology use for teaching, and beliefs about the value of technology for students' academic achievement. The e-mail included the questions as well as a link to the online survey. The invitation was sent to the respondents who had indicated they are currently teaching ($N = 418$). Because the first invitation to the original survey was sent with an anonymous link, there were 3 respondents who could not be matched for the follow-up e-mail. Of the 307 participants in the analyses, 256 responded to the follow-up survey.

Of those who had not responded at all to the original survey, or who had started it, but not completed the first set of questions about their access to computers at school (N=2,211), 245 (of which 213 were current teachers) responded. Those who had responded to the original survey, but were not currently teaching, did not receive the follow-up survey.

Pro-technology beliefs. A chi-square analysis was used to determine whether respondents to the study were as likely as non-respondents to agree strongly with the statement "Digital resources such as classroom technology and Web-based programs help my students' academic achievement." Although fewer respondents disagreed with the statement than non-respondents, the difference was not statistically significant

(χ^2 (N = 449) = 5.05, p = .28). The percentages of respondents and comparison teachers are presented in Table 4-2.

Table 4-2. Respondents and comparison teachers' pro-technology beliefs

	Respondents	Non-Respondents	US teachers
Agree Strongly	49%	49%	44%
Agree Somewhat	46%	42%	49%
Disagree somewhat or strongly	5%	9%	7%

In a survey of 40,000 American teachers (Scholastic, 2010), the proportion of teachers that agreed strongly was lower by 5%, while the proportion that disagreed (7%) fell between that of respondents (5%) and non-respondents (9%). The differences between the respondents in this survey and the percentages reported from the national survey were not statistically significant (χ^2 (N = 209) = 5.00, p = .08).

Use of computers with students. The respondents and non-respondents were similar in the frequency with which they planned for students to use computers during class time (χ^2 (N = 450) = 4.24, p = .37), with 53.7% of respondents, and 53.9% of non-respondents, reporting that they plan such use once a week or more. A survey of US teachers (PBS, 2010) reports that 40% of teachers use computers in the classroom "often," and 29% of teachers use computers outside the classroom often. The different scales make a statistical comparison impossible, however these proportions seem compatible with the rates reported by respondents. Table 4-3 presents the reported frequency of computer use.

Table 4-3. Respondents and comparison teachers' frequency of use with students

	NBCTs			US teachers	
	Respondents	Non-Respondents		in classroom /	outside
3x/week	24%	29%	Often	40%	29%
1x/week	29%	25%	Sometimes	29%	43%
Less than 1x/week	34%	37%	Rarely	19%	19%
Never	13%	9%	Never	10%	8%

Technology in classroom. The teachers in this study differed from the respondents to other published studies (PBS, 2010; Gray, Thomas, & Lewis, 2010) in the number who had access to various types of equipment available in the classroom. Fewer respondents reported having at least one computer (χ^2 (1, N = 307) = 499.33, p < .01), an interactive whiteboard (χ^2 (1, N = 307) = 4.65, p = .03), or a television (χ^2 (1, N = 307) = 18.78, p < .01) in the classroom. However respondents were more likely to report having a digital camera (χ^2 (1, N = 307) = 152.26, p < .01) than an average US teacher. Table 4-4 presents the proportions of respondents who reported having new technologies in the classroom.

Table 4-4. Respondents and comparison teachers' equipment access

	Respondents	US teachers
At least 1 computer	72.4%	97%
" " with Internet		over 80%
Interactive whiteboard	23.8%	28%
Television	69.1%	78%
Digital camera	37.1%	14%

Internet for teaching ideas. A Chi-square analysis showed a difference between respondents and non-respondents in the frequency with which they used an Internet resource to get teaching ideas (χ^2 (3, N = 451) = 9.51, p = .05). On average the respondents reported less frequent use of the Internet than the non-respondent NBCTs. Table 4-5 shows the frequency with which respondents and comparison groups reported using the Internet for teaching ideas.

Table 4-5. Respondents and comparison teachers' use of the Internet for teaching ideas

	Respondents	Non-respondents	US teachers
3x/week	36%	37%	27%
1-2x/week	27%	30%	35%
Less than 1x/week	34%	32%	36%
Never	2%	0%	2%

The number of respondents who use the Internet for teaching ideas was higher than participants reported in the MetLife Survey of the American Teacher: Past, present and future (Markow & Cooper, 2008), a nationally representative sample of 1,000 US teachers. A chi-square analysis indicated that the difference was statistically significant (χ^2 (3, N = 307) = 15.00, p < .01).

Summary: Response Bias

The fear that the online format led to underrepresentation of older respondents seems unfounded, as the respondents in this dissertation show a wide age range, and a higher average age than teachers both in the state and nation. Similarly, the topic does not appear to have biased the sample in that teachers in this study were comparable both to non-respondent NBCTs in California and to US teachers in the frequency with which they use technology with students, and in their beliefs about the value of technology in schools.

The fact that respondents use the Internet for teaching ideas more often than teachers in a nationally representative sample does raise the concern that the topic of technology use in teaching, or the online format of the survey, led to a more technologically inclined sample. The fact that both respondent and non-respondent NBCTs' use of the Internet for teaching ideas was higher than US teachers suggests that there may be a relationship between National Board Certification and the willingness to look for teaching ideas online. This underlines the danger of generalizing to less accomplished teachers. However, due to low response rates I cannot draw definite conclusions.

Studies of nationally representative teachers reported findings of higher access to computers, but the levels of other equipment were varied and inconclusive. Because the availability of computers is central to this study, it is important to consider what the implications of these differences might be. Lower numbers of teachers reporting access can be interpreted to mean that respondents happen to have less access than the average, or that the other studies happened to have samples with unusually high access. It is also possible that NBCTs really do tend to have less access to computers. It may be for example that as accomplished teachers, respondents to this survey were more critical of what they considered to be a working computer in their classroom.

Part 3: Representativeness

Scholars have argued that response representativeness is more relevant than the response rate (Sax, Gilmartin, & Bryant, 2003). For the purposes of this study, I wanted to know whether those teachers who responded reflect the characteristics of National Board Certified Teachers (NBCTs) in California. Furthermore, although

NBCTs were chosen specifically for their recognition as accomplished teachers, I was also interested in comparing these results to all teachers in California and the United States. In order to generalize from this sample to any larger population I needed to address the issue of the participants' representativeness.

Because the invitation was sent only to teachers who achieved National Board certification in California, the respondents were not intended to represent all teachers. Still, comparing the survey respondents who are currently teaching to the overall teacher population in California or in the United States helps to highlight potential segments of the population who may have been underrepresented, and suggests limits to the study's representativeness of other accomplished teachers. In this part of the chapter I compare respondents to non-respondents, Californian, and US teachers on the basis of gender, education level, ethnic group, and years teaching.

Gender

Women responded to the survey at a higher rate than would be representative of all Californian teachers (CDE, 2009). While women represent 72% of all teachers in California, 80.9% of the survey respondents were women, a statistically significant difference (χ^2 $(1, N = 303) = 11.79, p < .01$). The same is true in comparison with all US teachers (U.S. Department of Labor, 2009), where women comprise 82% of teachers at the elementary level (91.7% in this sample, χ^2 $(1, n = 133) = 8.53, p < .01$) and 55% at the secondary level (71.5% in this sample, χ^2 $(1, n = 165) = 72.49, p < .01$). However, the gender balance of survey respondents is consistent with previous studies of the proportions of men and women in California who are National Board Certified (Belden, 2002).

Education Level

Teachers in this study reported higher levels of education than typical Californian teachers (Rand California, 2007), with 79.3% of respondents having a Master's degree or above, as compared to 43.5% of Californian teachers. This difference was statistically significant (χ^2 $(1, N = 303) = 11.79, p < .01$). Table 4-6 shows the education levels of respondents and teachers in California.

Table 4-6. Respondents and comparison teachers' Education Levels

	Respondents	California teachers
BA	4.0%	13.9%
BA +	15.9%	42.3%
MA	35.4%	22.0%
MA +	40.4%	20.1%
Ed.D. / Ph.D.	4.3%	1.4%

Race/Ethnicity

Teachers in this study reported their race/ethnicity as White more often than is representative of Californian teachers (Ed-Data Partnership, 2009), and were less likely to report that they were Hispanic, Asian, or Black. A larger proportion of the respondents reported that they were Hispanic or Asian than is representative of teachers in the United States overall (U.S. Department of Labor, 2009). The distribution of teachers by race/ethnicity for respondents and comparison groups is presented in Table 4-7.

Chi-square analyses comparing respondents with the overall Californian teaching population showed that had significantly more white teachers ($\chi2$ (1, N = 304) = 8.96, $p < .01$) and fewer black teachers, ($\chi2$ (1, N = 304) = 4.00, $p = .05$) in this sample. Fewer Hispanic teachers participated in this study than in the general Californian population, a difference that approached statistical significance (χ^2 (1, N = 304) = 2.60, $p = .11$). The number of Asian teachers in this study was similar to the general population of Californian teachers (χ^2 (1, N = 304) = .29, $p = .59$).

Table 4-7. Race/ethnicity of respondents and in comparison teachers

	Respondents	CA teachers	US teachers	
			Elementary	Secondary
White	77.2%	70.1%		
Hispanic	13.6%	16.6%	7.1%	6.6%
Asian	4.6%	5.3%	2.4%	2.1%
Black	2.0%	4.3%	9.3%	7.8%
Native American	1.3%	0.5%		
Pacific Islander	1.0%	0.3%		
Filipino		1.5%		
Other/Declined	5.3%	1.5%		

Years Teaching

The average respondent in this study had almost 5 more years of teaching experience (M = 18.69, SD = 7.86) than an average teacher in California (M = 13.5 per Ed-Data Partnership, 2009). Eighty-four percent of respondents had taught for eleven or more years, as compared to 51% of teachers in the United States (Scholastic, 2010), a statistically significant difference ($\chi^2(2, N = 307) = 185.00, p < .01$). Respondents had an average of 3 more years of teaching experience than the non-respondents (M = 15.70, SD = 7.09), a statistically significant difference ($t(496) = 4.45, p < .01$). Table 4-8 presents the age distribution of participants and comparison groups.

Table 4-8. Teaching experience of respondents and in comparison teachers

Years	Respondents	US teachers
0-10	15.4%	49%
11-20	52.8%	25%
> 20	31.8%	26%

Summary: Representativeness

This set of analyses examined the extent to which the respondents were representative of other groups of teachers. Several results suggest that these respondents were not representative of other populations of teachers.

On average, the teachers in this study were older, more educated, and had more teaching experience than teachers in California and in the United States. The underrepresentation of black and Hispanic teachers and of men in this sample may reflect the demographic characteristics of teachers who choose to pursue certification, as evidenced by a study of NBCTs in 2001 that reported similar race/ethnicity and gender distributions (Belden, 2002).

It is important to recognize that there are other ways of demonstrating expertise in teaching, and that NBCTs may share other characteristics not examined here, that influence their responses. Further, there are many accomplished male and minority teachers whose perspective may not have been represented here. To the extent that race, ethnicity, or being male interacts with confidence in technological pedagogical content knowledge the findings in this dissertation should be interpreted with caution.

Chapter 4 Summary and Discussion

This chapter examined the characteristics of the respondents to this survey. Because of the low response rate, analyses explored whether the sample displayed obvious sources of bias and whether respondents could be considered representative of comparison populations.

The potential for response bias due to survey format and topic was examined. Older teachers were well represented in this survey, and respondents were not more technologically inclined than other teachers, as indicated by several measures of technology use and beliefs. Respondents did however report significantly lower levels of access to computers and significantly higher rates of use of the Internet for teaching ideas than reported by US teachers in other studies.

The analyses of demographic variables showed several dimensions on which respondents differed from Californian and U.S. teacher populations. The respondents to this survey can be characterized as more experienced, more highly educated, and older than average teachers in California and the United States. This might be explained by the focus on accomplished teachers. Underrepresentation of minorities and male teachers relative to the general population may be related to the demographics of teachers who choose to pursue National Board Certification. However, without information about these variables in the population of NBCTs in California, I hesitate claim that the respondents to this survey are representative of even this limited population. These analyses contribute one set of findings to the ongoing discussion about the nature of TPACK and its development; more research is needed to explore the extent to which the findings in this dissertation hold true for other groups of accomplished teachers.

Chapter 5: What the Measures Measured

In this chapter I address the broad question "What is associated with greater confidence in technological pedagogical content knowledge (TPACK)?" by examining how the measure of TPACK confidence relates to 1) measures of confidence in the other knowledge domains in the TPACK framework 2) reported skills, beliefs, and experience with technology and teaching, and 3) indicators of technology use with students.

TPACK refers to the special knowledge required to effectively support student learning through use of new technologies (Mishra & Koehler, 2006). The items in the survey asked respondents to rate the degree to which they agreed with statements such as "I can choose technologies that enhance the [math] content for a lesson." They solicited participants' own assessment of their own abilities. The statements included items related to knowledge (e.g., "I know about a lot of different technologies") and to confidence in teaching with technology (e.g., "I can adapt the use of the technologies that I learn about to different teaching activities"). Because the measures did not actually test what the respondents did or did not know about technologies and their use in teaching, I refer to the average responses to these scales as confidence scores.

Domains

Seven knowledge domains are included in the TPACK framework. The current study included confidence measures for five of the seven domains related to TPACK: technological knowledge (TK) 7 items, pedagogical content knowledge (PCK) 1 item, technological content knowledge (TCK) 1 item, technological pedagogical knowledge (TPK) 5 items, and technological pedagogical content knowledge (TPACK) 5 items. Due to their position in the survey, there is a risk of set bias, which I discuss at the end of the chapter. Exploratory factor analysis uncovers patterns in the data consistent with TPACK, TPK, and TK domains in the framework, and the internal consistency of the scales was high. I then explore these three confidence scores' relationship to each other, expecting that though related, they will show differences as well.

Skills, Beliefs, and Prior Experience

The confidence scores are used to explore the relationship between confidence in using technology to support learning (TPACK), and factors that should be positively correlated with it: measures of technology *skills*, *beliefs* about technology, and *prior experience* with technology and teaching.

Skills. Although TPACK requires some knowledge of technology knowledge (TK), TPACK also relies heavily on pedagogical content knowledge (PCK) and is very specific to the teaching context (subject, students, and school) in which it is applied. Therefore I expect that, though correlated, TPACK and TK will show meaningful differences when compared to a measure of general technology skill, represented in this study by items related to Internet searching (Hargittai, 2005). I expect that TK will correlate more strongly with the skills measure, while TPACK will show a weaker, but still meaningful, relationship.

Beliefs. The relationship between technology use in teaching and pro-technology beliefs is well documented (e.g., Ertmer, 2005; Hermans, Tondeur, Valcke, & van Braak, 2006; Windschitl & Sahl, 2002). Teachers who are more positive about technology in general tend to find ways to use new technology tools to support student learning. I expect that TPACK confidence will also show a positive relationship to beliefs about the value of technology in teaching.

Experience. Finally, the relationship between technology experience and attitudes has long been shown to be strong (Barron, 2004; Chen, 1986). Individuals with more experience using technology tend to express more positive attitudes toward it. Teachers with more experience using computers at home have also been shown to use them more in teaching (Williams, Coles, Wilson, Richardson, & Tuson, 2000). Given that experience has been shown to relate to positive attitudes and more frequent use, I expect it will also relate to higher TPACK.

More teaching experience has also been shown to relate to more educationally sound use of technology in classrooms (Hughes, 2005; Meskill, Mossop, DiAngelo, & Pasquale, 2005; Russell, Bebell, O'Dwyer, & O'Connor, 2003). It is not clear however whether that relationship is due to the passage of time, or to higher pedagogical content knowledge. In these analyses I explore the degree to which technology experience and teaching experience relate to respondents' confidence in their technological pedagogical content knowledge.

Student Use

Many scholars currently working to define and measure TPACK do so in the hopes of ultimately encouraging teachers to use new technologies to transform the learning experiences of students. Technology has been seen as important not only as a critical skill set for students, which allows them access to today's "participatory culture" (Jenkins, 2006), but also as enabling a range of "learning and innovation skills" (Partnership for 21st Century Skills, n.d.) or "digital-age learning skills" (ISTE, 2007). The National Educational Technology Plan argues that schools must leverage technology "to provide engaging and powerful learning experiences and content" (U.S. Department of Education, 2010, p. ix). The final question in this chapter then becomes the extent to which respondents' TPACK confidence relates to measures of their technology use with students. Because prior studies have shown that use of computers with students is impacted by the availability of computers in schools (Becker, 2000; Forssell, 2009), the relationships are examined separately for different levels of computer access. In addition, age and gender are controlled to determine whether the relationship between knowledge and technology use is different for male and female teachers, or for teachers of different ages. Finally, teaching assignment is controlled to examine whether the relationship between knowledge and technology use differs among teachers at different grade levels and for different subject areas.

Organization of the Chapter

In part 1 of this chapter, factor analysis is used to explore the patterns that appear in the data, allowing a comparison to the sub-constructs in the TPACK framework. The sub-constructs include technological knowledge (TK), technological pedagogical knowledge (TPK), pedagogical content knowledge (PCK), technological content knowledge (TCK), and technological pedagogical content knowledge (TPACK). The PCK and TCK constructs were represented by only one item each, and loaded on the same factor as TPACK. Given that high PCK was assumed for all participants, and that the TCK item did not distinguish meaningfully from TPACK, those constructs were not analyzed further. Bivariate correlations and distributions are used to explore the relationship between the TPACK, TPK, and TK scale scores.

Further analyses in part 2 of the relationship with measures of skills, beliefs, and experience related to teaching with technology serve to examine the nature of the construct being measured in the TPACK scale. A measure of respondents' Internet search skills serves to test the distinction between technology knowledge and technological pedagogical content knowledge. The relationship between beliefs and TPACK confidence is explored using measures of beliefs related both to technology in general, and to technology use in teaching. Finally, measures of respondents' personal and classroom experience with technology are compared to their confidence in their TPACK.

In part 3, the hypothesis is tested that teachers' confidence in their knowledge of how to support student learning using new technologies will relate to higher levels of technology use with students. The nature of the relationship is tested with two measures of student computer use: frequency of use during class and breadth of exploration of different production activities with students. To determine how robust the relationship between TPACK confidence and computer use is, the analyses are repeated separately controlling for several relevant factors: computer availability, gender, age, subject taught and grade level.

For each part of this chapter, the relevant measures are presented first, followed by the analyses. Each part of this chapter ends with a summary of findings and their implications. A discussion of the findings across all three parts concludes the chapter.

Part 1: Relationships between Constructs in the TPACK Framework

This part of the chapter examines the relationships among the measures of confidence in the knowledge domains included in the TPACK framework: technological knowledge (TK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK). Specifically, I seek to answer the questions of whether these measures capture the distinctions suggested by the framework, and the degree to which they relate to each other.

Measures: Constructs

Survey items for pre-service teachers developed by Denise Schmidt and her colleagues (2009) were modified for use with in-service teachers. The original survey was created for and tested with preservice teachers majoring in elementary or early childhood education. For this study, references to pre-service education were removed or modified to reflect the experiences of in-service teachers. Where the original items were not specific about content area, the survey tool was used to present content-specific items that reflected the subjects that teachers reported they currently taught. Thus the original survey item "I can use strategies that combine content, technologies and teaching approaches that I learned about in my coursework in my classroom" became "I can use strategies that combine [math] content, technologies, and teaching approaches that I learned about elsewhere, in my classroom." Table 5-1 presents examples of items from the TPACK-related constructs. All 5 TPACK items appear in Table 5-2. A table of all measures is provided in Appendix A, and the full survey is available in Appendix B.

Around the middle of the survey, the 5 TPK items were presented on one page, followed by a page of 5 TPACK, 1 TCK, and 1 PCK items for each subject taught. The 7 TK items appeared on one page near the end of the survey. For all measures related to the TPACK framework, teachers responded on a 5-point scale from Strongly Disagree (1) to Strongly Agree (5) to each statement.

TPACK Confidence Scale

In the survey of pre-service teachers (Schmidt, et al., 2009), the TPACK scale included 1 item each for English, Math, Science, and Social Studies, as well as four items in which the content area was left unspecified (e.g., "in my classroom" or "the content for a lesson"). I modified the four items to reflect subject areas and used them together with the original subject-specific item for each subject area taught, for a total of 5 TPACK items per subject taught. The 5 TPACK items for each subject were presented together with the PCK and TCK items for that subject in random order on one page near the middle of the online survey.

Table 5-1. TPACK-related Constructs

Construct	Example survey item	Items
Technological Knowledge (TK)	*I know about a lot of different technologies*	Scale (7 items)
Technological Pedagogical Knowledge (TPK)	*I can adapt the use of the technologies that I learn about to different teaching activities.*	Scale (5 items)
Technological Pedagogical Content Knowledge (TPACK)	*I can choose technologies that enhance the [math] content for a lesson.*	Scale (5 items)
Technological Content Knowledge (TCK)	*I know about technologies that I can use for understanding and doing [mathematics].*	1 item
Pedagogical Content Knowledge (PCK)	*I know how to select effective teaching approaches to guide student thinking and learning in [mathematics].*	1 item

Responses to the 5 items in which respondents rated their technological pedagogical content knowledge (TPACK) were averaged for each subject area taught. The highest TPACK self-rating across subjects for any respondent became the TPACK confidence score. Averaged scores ($N = 307$) ranged from 1 to 5. The distribution was negatively skewed, with a mean of 3.91 and a standard deviation of .80; it is illustrated in Figure 5-1 in the analyses.

TPK Scale

The 5 items in which respondents rated their technological pedagogical knowledge (TPK) were averaged. Averaged scores ($N = 305$) ranged from 1 to 5. The distribution was negatively skewed, with a mean of 4.07 and a standard deviation of .67; it is illustrated in Figure 5-2 in the analyses. The 5 TPK items were presented in random order on one page in the middle of the online survey.

TK Scale

The 7 items in which respondents rated their technological knowledge were averaged to form a scale score. TK scale scores ($N = 301$) ranged from 1 to 5, with a mean of 3.23 and a standard deviation of .87; it is illustrated in Figure 5-3 in the analyses. The 7 TK items were presented in random order on one page near the end of the online survey.

Analyses: Constructs

Discriminant Validity of Constructs

In order to determine whether participants' responses to the TPACK scale validated the sub-constructs in the TPACK framework, I performed an exploratory factor analysis on the combined TK, TPK, PCK, TCK, and TPACK items. Because there were separate questions for each content area, and many participants received questions for multiple subjects, each of the disciplinary areas was analyzed separately. Prior to performing the exploratory factor analyses, the correlation matrices were examined to determine the suitability of the data for factor analysis. Many correlation coefficients above .3 were present. The Kaiser-Meyer-Olkin values were well above the recommended value of .6 (Kaiser, 1970) and Bartlett's Test of Sphericity (Bartlett 1954) reached statistical significance, indicating that the correlation matrices were factorable. The exploratory factor analysis was performed using a principal components extraction; because the constructs were strongly correlated with each other (r = .46 to .65), Oblimin rotation with Kaiser Normalization was used to help interpret the three components (Pallant, 2010).

For all subject areas, three main components emerged with eigenvalues greater than 1, together explaining over 70% of the variance in the data. As an example, the results for the analysis of Social Studies content showed the three-component solution explained 72.6% of the variance, with the three components contributing 54.2%, 12.1%, and 6.3% respectively. The exact variance explained differed by subject area. The solutions for Math, Science, and English/Language Arts explained 71.6%, 74.0%, and 72.2% of the variance, respectively.

The rotated solutions for all subject areas showed that each of the three components showed 5 or more strong loadings, and each variable loaded substantially on only one component. The interpretation of these components is consistent with the constructs in the TPACK framework: TPACK (component 1), TK (component 2), and TPK (component 3). The coefficients of the exploratory factor analyses related to

Table 5-2. Pattern and Structure Matrix for Factor Analysis with Oblimin Rotation of Three Factor Solution of TPACK items for Social Studies

Item	Theoretical construct	Pattern coefficients			Structure coefficients			Communalities
		1	2	3	1	2	3	
I know about technologies that I can use for understanding and doing social science.	TCK	**.90**	-.02	.04	**.92**	.52	.62	.69
I can teach lessons that appropriately combine social studies, technologies and teaching approaches.	TPACK	**.87**	.03	.04	**.92**	.45	.61	.70
I can choose technologies that enhance the social studies content for a lesson.	TPACK	**.86**	.08	.03	**.92**	.48	.62	.75
I can use strategies that combine social studies content, technologies, and teaching approaches that I learned about elsewhere, in my classroom.	TPACK	**.85**	.16	-.03	**.91**	.52	.63	.71
I can select technologies to use in my classroom that enhance what I teach and what students learn.	TPACK	**.84**	.07	.06	**.91**	.57	.59	.80
I can provide leadership in helping others to coordinate the use of social studies content, technologies, and teaching approaches at my school and/or district.	TPACK	**.69**	.19	.02	**.79**	.54	.54	.65
I know how to select effective teaching approaches to guide student thinking and learning in social studies.	PCK	**.62**	-.16	.13	**.63**	.21	.46	.61
I can learn technology easily.	TK	-.05	**.86**	-.01	.53	**.89**	.44	.72
I know about a lot of different technologies.	TK	.13	**.83**	-.02	.49	**.86**	.43	.74

Item	Theoretical construct	Pattern coefficients			Structure coefficients			Communalities
		1	2	3	1	2	3	
I keep up with important new technologies.	TK	.08	**.82**	.00	.45	**.84**	.45	.62
I know how to solve my own technical problems.	TK	.04	**.82**	-.02	.37	**.83**	.35	.79
I frequently play around with technology.	TK	-.01	**.80**	.10	.43	**.83**	.37	.75
I have had sufficient opportunities to work with different technologies.	TK	-.15	**.73**	.23	.53	**.79**	.38	.42
I have the technical skills I need to use technology.	TK	.23	**.71**	-.09	.36	**.76**	.46	.84
I am thinking critically about how to use technologies in my classroom.	TPK	-.10	.01	**.95**	.51	.39	**.89**	.84
I can adapt the use of the technologies that I learn about to different teaching activities.	TPK	.02	.04	**.83**	.58	.43	**.86**	.84
I can choose technologies that enhance students' learning for a lesson.	TPK	.13	.09	**.72**	.64	.48	**.85**	.85
I can choose technologies that enhance the teaching approaches for a lesson.	TPK	.18	.05	**.69**	.65	.45	**.83**	.65
My experiences have caused me to think more deeply about how technologies could influence the teaching approaches I use in my classroom.	TPK	.18	-.02	**.67**	.60	.37	**.78**	.85

Note: Major loadings for each item in bold.

Social Studies content items are presented in Table 5-2. The PCK and TCK constructs were measured with only one item each, which were presented on the same page as the TPACK items. For all subjects, those PCK and TCK items loaded on the same component as the items from the TPACK scale. However, because the PCK and TCK items were intended to capture a different theoretical construct, I did not include them in the TPACK scale measure.

Internal Consistency of Scale Measures

To further determine whether the items in each scale were internally consistent, reliability analyses were run on each construct scale. Schmidt, et al. (2009) reported strong internal consistency for the original survey; the modified items used for this study were also strongly consistent. Table 5-3 presents Cronbach's alpha coefficients for the TK, TPK, and TPACK scales for both surveys.

Table 5-3. Internal Consistency of Sub-scales in original and modified TPACK Surveys

Scale	Items	Original survey Pre-service	Modified survey In-service
TK	7	.82	.92
TPK	5	.86	.90
TPACK	8	.92	
English	5		.94
Math	5		.94
Science	5		.95
Social Studies	5		.94

Relationships Between Sub-Constructs in the Framework

Bivariate Correlations. Table 5-4 presents the bivariate correlations between the measures of the sub-constructs in the TPACK framework. The averaged scale values for respondents' confidence in technological knowledge (TK), technological pedagogical knowledge (TPK), and the highest of each respondent's technological pedagogical content knowledge scores (TPACK) were compared. Because the PCK and TCK measures consisted of only one item on the survey, and because those items loaded with the TPACK items in the exploratory factor analysis (reflecting a possible response set bias), I did not include them in these analyses. The three scale scores—TPACK, TPK, and TK—showed statistically significant correlations with each other at a significance level of less than .01. The technical knowledge (TK) scale score shared roughly one-third of its variability with the pedagogical (TPK, 29%) and content (TPACK, 34%) scores. The pedagogical (TPK) and content (TPACK) scores shared over half of their variability, a very large effect size (Cohen, 1988).

Table 5-4. Correlations among respondents' confidence in TK, TPK, and TPACK.

	Pearson Correlation (*df*)	
	TPK	TPACK (Highest)
TK	.543 (301)**	.593 (301)**
TPK		.737 (305)**

** Correlation is significant at the .01 level (2-tailed).

Distributions. Further insights into the relationship between these three confidence scores can be derived from a closer examination of their distributions, which are illustrated in figures 5-1, 5-2, and 5-3. All three show a spike at 4.0, which corresponds with "Agree" on the 5-point scale. The TPACK and TPK distributions also show a secondary spike at 5.0, corresponding to "Strongly Agree."

The TPACK and TPK distributions were skewed to the right, or high, end of the scale, indicating that most respondents rated themselves highly knowledgeable. The TK distribution was more evenly distributed across the full range of the scale.

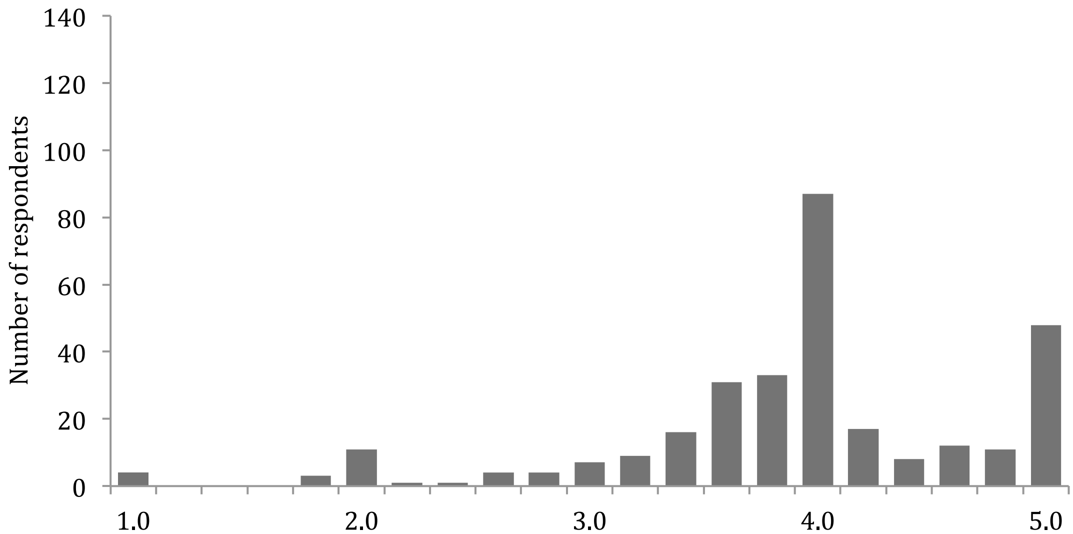

Figure 5-1. The distribution of highest TPACK confidence scores. Scores were an average of 5 survey items. Respondents in this sample tended to rate their technological pedagogical content knowledge highly.

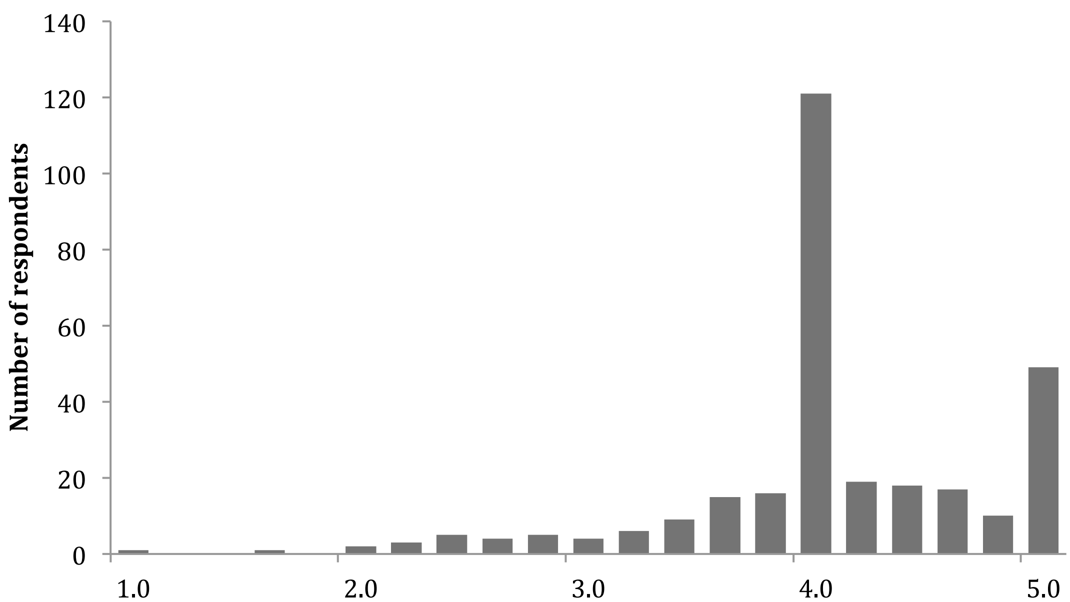

Figure 5-2. The distribution of TPK confidence scores. Scores were an average of 5 survey items. Respondents in this sample tended to rate their technological pedagogical knowledge highly.

TK Scale

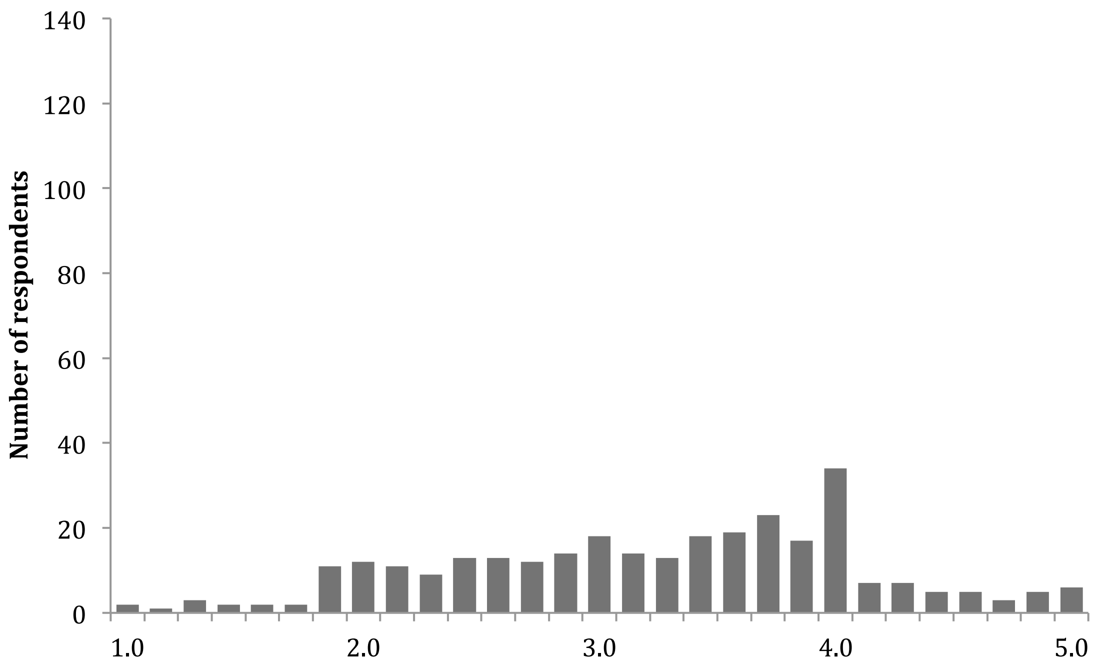

Figure 5-3. The distribution of TK confidence scores. Scores were an average of 7 survey items. The distribution of confidence in technology knowledge was less skewed than the TPK and TPACK confidence measures.

Summary: Constructs

The analyses presented in part 1 suggest that the survey items intended to measure the different constructs that are part of the TPACK framework were largely successful. Both the exploratory factor analysis and the bivariate correlations supported the assertion that the TK confidence score measured a different underlying construct than the TPK and TPACK confidence scores. The possibility of having relatively low TK but high TPACK is intriguing, and raises questions about the nature of the technologies and the reference points evoked by the questions.

The items measuring pedagogical content knowledge (PCK) and technological content knowledge (TCK) did not separate from the TPACK construct in the exploratory factor analysis. This may be due to the high level of accomplishment of the survey respondents, the placement of the items on the survey, a poor match between the questions and the constructs, or it may reflect a lack of perceived difference between the constructs from the point of view of the respondents. Whether teachers view TPACK as being separable from pedagogical content knowledge and technological content knowledge is a question worthy of further exploration.

The TPK and TPACK confidence scores, though distinct in the factor analysis, were still closely related to each other, sharing over 50% of their variability. A closer look at the factor analysis suggests that the first component, associated with TPACK, accounted for the lion's share of the variability in the data; TPK was associated with the third component, which accounted for relatively little. The distributions of the TPACK and TPK confidence scores were also similar, with most respondents tending to the high end of the scale, and spikes at 4.0 and 5.0. It may be that the use of technology in schools requires a much more limited and more easily mastered knowledge base. However the tendency of scores to spike suggest that respondents were not attending as carefully to the distinctions made in the individual survey items; respondents may have been providing a more general response to their perception of the idea behind the questions. As such these scores may measure more than knowledge of how to use technology in teaching. Given the high accomplishment of the respondents as National Board Certified teachers, the scores may be confounded by a sense of their identity as experts in their field. The relatively even distribution of TK scores across the full range of the scale lends credence to this interpretation. More research is needed to explore how respondents interpret the survey items relating to TPACK and TPK.

There is one key caveat to the assertion that TPACK and TPK confidence scores are measuring a different construct than the TK confidence score however, related to the survey implementation. Following the example of the original survey (Schmidt, et al., 2009), items for each scale were presented together. The TPK items were presented on the page before the TPACK items in the middle of the survey, while the TK items were presented at the end. This presents potential problems, as the internal validity of items within each scale may be due to their proximity, creating a response set bias. Studies of other survey instruments have shown that scrambling the items can decrease the scale consistency and change the factor loadings (e.g., Ruble & Stout, 1990). The finding that the PCK and TCK items, which were presented together with the TPACK items, loaded on the same factor suggests that such a bias may have played into these findings. The proximity of the TPK and TPACK scales to each other may also have increased the similarity of their responses.

Based on these analyses, care must be taken before making claims about the distinctions made by teachers between TPK and TPACK. While acknowledging that more work must be done to examine whether response set bias is creating a false sense finding of consistency among the survey items, I will assume that the theoretical distinction between knowledge of technology (TK), and knowledge of how to use technology to support student learning (TPACK), was adequately captured by the instrument. The next part of this chapter will explore the relationship of these two scale items to measures of skills, beliefs, and experience.

Part 2: Skills, Beliefs, & Experience

Part 2 of this chapter explores the relationship of TPACK and TK confidence scores to measures of technology skill; beliefs relating to technology in general and to technology in teaching; and respondents' technology and teaching experience. Prior research suggests positive relationships should appear between all these measures, with the possible exception of teaching experience. Popular wisdom seems to hold that knowledge of new technologies is more common among younger teachers, leading us to expect a negative correlation with years of teaching experience as well. But TPACK builds on teaching expertise as well as technology knowledge. In many studies, years of service are proxy for pedagogical content knowledge (PCK). Given that all respondents to this study are assumed to have high PCK, I expect no significant relationship between TPACK and years teaching.

Measures: Skills, Beliefs, & Experience

Skills

On a scale developed and validated by Hargittai (2005), participants rated their familiarity with 27 Internet-related terms from none (1) to full (5). The scale has been shown to correlate highly with observed search behaviors on the Internet. Each participant received a score based on the average of all items completed, not including three additional bogus terms, which were used as a validity check. Scores ranged from 1.2 to 4.96, with a mean of 2.74 (*SD* = .84).

Beliefs

Using the TPACK model as a framework, I created scale measures of respondents' beliefs about technology and about the use of technology to support student learning of a particular subject or topic (TPC). For more on the development of these items please see Chapter 3. Multiple items were averaged to give scale scores.

Technology Beliefs. The 6 items in which respondents rated their beliefs about technology showed internal consistency (Cronbach's α=.69). Averaged scores (*N* = 302) ranged from 2.33 to 5. The distribution was negatively skewed, with a mean of 3.76 (*SD* = .54).

Technology-Pedagogy-Content Beliefs. The 8 items in which respondents rated their beliefs about the value of using technology to support teaching of content were reverse-coded where appropriate and then averaged for each subject area taught. The scales showed high internal consistency, with Cronbach's α ranging from .84 to .89 depending on subject area. The highest beliefs scale across subjects for any respondent became the TPC-Beliefs score. Averaged scores (*N* = 264) ranged from 2.25 to 5. The distribution was negatively skewed, with a mean of 3.93 (*SD* = .57).

Experience

Years teaching. Teachers in this sample (*N* = 307) had taught for a minimum of 6 and a maximum of 46 years. The average number of years taught was 19.15 (*SD* = 7.89).

Frequent use of technology at home. Two measures of teachers' personal computer use were generated from 6 survey items. The items asked participants how often they used computers and/or the Internet for the following personal tasks: read or send e-mail; learn information about a topic that is of personal interest; talk to others online about a hobby; play games; work on digital media projects; edit a blog or social networking page. Responses were recoded and aggregated to reflect how many of the 6 activities the participant engaged in at least weekly. Tallies of *weekly home use* ranged from 1 to 6, with a mean of 3.42 and a standard deviation of 1.28. (*N* = 297).

Similarly, tallies of *daily home use* ranged from 1 to 6, with a mean of 2.17 and a standard deviation of 1.18 (N = 297).

Student Frequency of Use

A measure of frequency of computer use with students was included in the follow-up survey sent to the respondents who had indicated they are currently teaching. Participants were asked "On average, how often do you plan for a typical student to use a computer during class?" Of the 209 participants in this study who responded to this question, 56% planned for students to use computers in class at least weekly.

Production Activities

Items developed by Barron (2004; 2006) were used to measure the extent to which participants had asked students to engage in activities that asked them to create products using new technologies. The 16 activities relate to creativity and innovation, collaboration and communication, or critical thinking and problem solving. Respondents were asked to indicate the number of times they had participated in each activity from a choice of: never, 1-2 times, 3-6 times, and 7+ times.

The total number of activities respondents had ever engaged in personally became their *personal exploration* score. Participants' personal exploration scores ranged from 0 to 16, with a mean of 6.78 (SD = 3.08, N = 304). The modal number of activities ever experienced was 6 or 7.

The number of activities respondents had engaged in three or more times for personal tasks became their *personal repeat* score. Participants' personal repeat scores ranged from 0 to 13, with a mean of 4.24 (SD = 2.68, N = 304). The modal number of activities experienced three or more times was 4.

The total number of activities respondents had ever asked their students to engage in during class time became their *student exploration* score. Participants' student exploration scores ranged from 0 to 15, with a mean of 3.95 (SD = 3.39, N = 302). The modal number of activities ever assigned to students was 0.

The total number of activities respondents had asked their students to engage in during class at least three times became their *student repeat* score. The average student repeat score was 1.91 (*SD* = 2.35, range = 0 to 13, *N* = 302). The modal number of activities assigned to students three or more times was 0.

Analyses: Skills, Beliefs, & Experience

Skills

Bivariate correlations were run with a measure of familiarity with Internet terms, which has been shown to relate to observed Internet searching behaviors (Hargittai, 2005). The scores on the Internet skills measure correlated strongly with confidence in technological knowledge (TK), sharing over 50% of their variability, $r(301) = .71$, $p < .01$. The Internet skills measure correlated moderately with technological pedagogical content knowledge (TPACK), sharing 16% of their variability $r(300) = .41$, $p < .01$. Higher scores on the Internet skills measure were associated with higher confidence in both TK and TPACK.

Beliefs

Technology Beliefs. The scores on the scale measure of technological beliefs correlated with TK confidence, $r(297) = .29$, $p < .01$, with higher technology beliefs associated with higher confidence in TK. Higher scores on the technology beliefs measure were also associated with higher TPACK confidence but the relationship was weaker, $r(302) = .19$, $p < .01$. Although statistically significant this represents a relatively small effect size (Cohen, 1988).

TPC Beliefs. The technological pedagogical content (TPC) beliefs scores correlated with TPACK confidence, sharing 16% of their variability, $r(264) = .40$, $p < .01$. This represented a medium effect size (Cohen, 1988). Higher scores on the TPC beliefs measure were associated with higher TPACK confidence. Higher scores on the TPC beliefs measure were also associated with higher TK confidence. However, the relationship with TK confidence was weaker, $r(261) = .22$, $p < .01$.

Experience

Bivariate correlations examined the relationship between TPACK and experience relating to teaching (years teaching), use of computers with students (frequency and breadth), and personal technology use (frequency and breadth). These correlations are presented in Table 5-5.

Table 5-5. Correlations between teachers' TPACK and TK confidence ratings, and experience variables

	TPACK			TK		
	N	*r*	*p*	*N*	*r*	*p*
Classroom Experience						
Years Teaching	307	-.07	.22	301	-.19	<.01
Computer Use Frequency with Students	209	.26	<.01	206	.14	.05
Exploration of Activities	302	.38	<.01	297	.40	<.01
Repeat Activities	302	.34	<.01	297	.39	<.01
Personal Experience						
Weekly Home Use of Computers	297	.22	<.01	294	.45	<.01
Daily Home Use of Computers	297	.24	<.01	294	.43	<.01
Exploration of Activities	304	.44	<.01	299	.61	<.01
Repeat Activities	304	.44	<.01	299	.58	<.01

Note: For frequency measures, correlations reported are Spearman's rho rank-order correlations, a non-parametric test. For measures of the number of activities, Pearson product-moment correlations are reported.

The number of years teaching showed a weak but statistically significant negative relationship to technology knowledge. Teachers with more teaching experience tended to rate their technology knowledge lower. However, teaching experience did not show a significant relationship to participants' ratings of their confidence in using technology for teaching.

All the other experience variables were positively and significantly correlated with both confidence measures. Of the experience variables, those based on a frequency of use measure (daily home use, weekly home use, and student frequency use) showed a small correlation with TPACK confidence, while the measures based on breadth of experience with production activities (personal exploration, personal repeat, student exploration, student repeat) all showed a medium correlation with the TPACK confidence measure. For TK confidence the same pattern held, but with some differences. The correlation with frequency of student computer use was smaller than for TPACK confidence, while the correlations with frequency of home use measures were stronger. The correlations with breadth of experience measures at school were equivalent to the TPACK confidence relationships, but stronger for the breadth of experience measures at home.

Summary: Skills, Beliefs, and Experience

In part 2 I examined the relationships between the TPACK and TK confidence scores and measures of skills, beliefs, and experience. The findings showed the expected relationships. Confidence in technology knowledge (TK) correlated more strongly than TPACK confidence with beliefs about the value of technology and with technology skills (a measure of familiarity with Internet terms that has been shown to relate to observed search skills). TPACK confidence showed stronger relationships than TK confidence with beliefs about the value of using technology to teach content (TPC). The correlations between TPACK confidence and classroom-based experience measures were stronger or equivalent to the correlations with TK confidence. In measures of personal technology use, TK confidence correlated more strongly than TPACK confidence. Years of teaching experience showed a weak negative correlation with TK confidence, but no significant relationship to TPACK confidence.

The relationship between TPACK and TK confidence and measures of prior experience showed a higher correlation for the measures of breadth of experience (the number of activities ever attempted) than for the frequency of use measures. This relationship held true for both TPACK and TK, and in both school and home. The implications of this finding will be explored more fully in the discussion at the end of the chapter.

Despite the high-level alignment of these findings with expected results, the details also raise questions about the relationship between TK and TPACK. The fact that Internet search skills are more strongly correlated with TK confidence than with TPACK confidence, together with the fact that respondents as a whole tended to rate their TPACK more highly than their TK (see part 1), suggest that it is possible to have high TPACK without high TK. TPACK is not simply the addition of TK to PCK. There are several possible explanations, among them:

1) Although the use of the Internet is a relevant and common use of technology in classrooms, and as such, teachers using technology with students might reasonably

be expected to know how to search well too, in fact teachers don't need Internet search skills in order to support student use of technology in the classroom. The subset of TK needed for TPACK doesn't include this particular technology, or it is only one of many ways of demonstrating proficiency with technology.

2) The self-report nature of the TK, TPACK, and skills measures is failing to capture the true knowledge base of the respondents, with some high-TK respondents rating themselves lower than they should on both the TK confidence and Internet skills measures. The confidence measures may be subject to influence by the participants' perceptions of the abilities of others; individuals who compare themselves to high-tech users when rating their TK may compare themselves to less tech-savvy colleagues when rating their TPACK. We need to keep in mind participants' position within social networks, and develop better measures to objectively assess knowledge.

3) Strong TPACK relies more on strong PCK than on strong TK. Although some technology knowledge may be needed for TPACK, the standard may be quite low. Although all respondents are assumed to be accomplished teachers based on their National Board certification, their responses to the TPACK items may be an indication of the degree to which they are confident that they can adapt their expertise to new conditions.

4) Other factors are modifying the relationships between TPACK and measures of technology skills, beliefs, and experience. For example, though confident about their capacity to use technological tools, teachers may not have the opportunity to learn or apply the actual knowledge due to lack of access to computers. To address this possibility, I examine in more detail the relationship between TPACK and student computer use measures next.

Part 3: Relationship to Student Use

In part 2 above, technological pedagogical content knowledge (TPACK) was shown to relate to several measures of experience using new technologies with students. In this part of the chapter, the relationships between teachers' TPACK and their reports of students' opportunities to learn with new technologies are examined more thoroughly, while controlling for several potentially confounding variables. The focus here is not on the measures of student use, but on the relationship between them and TPACK. These analyses provide additional insights into the nature of the construct measured by the TPACK scale.

To explore patterns in the data I focus on two measures of technology use in the classroom. The first is the measure of frequency, in which respondents indicated how often they typically ask students to use computers during class time. This frequency measure is similar to measures used by many researchers to quantify technology use in classrooms. The second measure captures a historical retrospective, asking how many of 16 different production activities participants have ever assigned to students in class. The number of activities respondents had repeatedly assigned to students represents a breadth of experience measure.

Public debates about teachers and technology often refer to age as impacting use, with many expecting that younger teachers will naturally use more technology in teaching. However, studies have shown that the relationship between age and technology use is less straightforward; indeed, more experienced teachers often use technology more to support learning than their younger colleagues (Hughes, 2005; Meskill, Mossop, DiAngelo, & Pasquale, 2005; Russell, Bebell, O'Dwyer, & O'Connor, 2003). We know that age does not relate to TPACK, but here I examine the possibility that age impacts the relationship between TPACK and use of technology with students by controlling for age of the respondent.

Men's ratings of their own technological competence has often been shown to be higher than women's; in many studies, men are shown to both rate their own competence higher, and have more experience using new technologies (e.g., Li & Kirkup, 2007; Vekiri & Chronaki, 2008). However, there is evidence that the difference may be disappearing (Imhof, Vollmeyer, & Beierlein, 2007), and other studies have shown that when experience is controlled, gender differences disappear (Barron, 2004; Chen, 1986). In these analyses I examine whether the relationship between TPACK and classroom technology use is different for men and women.

Previous research has indicated that teachers with 5 or more classroom computers are more likely to have their students use computers frequently (Becker, 2000); here I examine whether the relationships between TPACK and frequency, and between TPACK and breadth of experience, hold steady when the availability of classroom computers is controlled for. Furthermore, “autonomous” computing—the anywhere, anytime access made possible by a mobile computer—has been shown to relate to more diverse activities and higher skill (Hargittai, 2010). Teachers with a combination of 5 or more classroom computers and a teacher laptop have been shown to use a broader range of activities with students (Forssell, 2010). Therefore the nature of the relationships between confidence in TPACK and both student use measures are examined for teachers with and without teacher laptops.

Measures: Student Use

Student Use

Two measures of technology use with students from part 2 of this chapter were used again in this set of analyses. The *frequency* measure captured how often respondents planned for a typical student to use a computer during class. The *breadth* measure captured how many different production activities respondents had assigned to students 3 or more times.

Age

A total of 256 participants reported the year they were born. The year was subtracted from 2010 (the year of the study) to calculate the participant’s age. Ages ranged from 30 to 66 (M = 48.9, SD = 9.07).

Gender

Of the 303 participants who reported their gender, 58 men (19.1%) and 245 were women (79.8%). This reflects the gender distribution of National Board Certified Teachers reported in another study of NBCTs (Belden, 2002).

Classroom Computers

Participants were asked “What kinds of digital technology do you have access to in your classroom or where you teach? (Check all that apply. If you teach in several locations, check what you have access to anywhere. For number of computers, enter the highest number in any one place.)” Responses for desktop and laptop computers were combined. Based on research suggesting that having 5 or more computers in the classroom is related to more frequent use with students (Becker, 2000), a dichotomous variable was created indicating whether there were 5 or more computers in the classroom. Overall, 33.2% of participants in this study reported having the higher level of classroom access.

Teacher Laptop

Participants were asked to indicate whether they had a "teacher computer (laptop) … in your classroom or where you teach." This data set does not indicate whether the school or the respondent provided the laptop. Roughly half (55%) of the respondents indicated that they have a teacher laptop. Of the respondents *without* a laptop for teaching, 75% reported that they do have a desktop computer to use for teaching. The remaining 25% (35 teachers) were predominantly elementary teachers.

Analyses: Student Use

Table 5-6. Technology use correlations with TPACK

	n	*r*	*p*
Frequency of Use			
Controlling for age	167	.26	<.01
Men	45	.48	<.01
Women	161	.13	.08
0-4 computers	131	.12	.17
5+ computers	78	.20	.08
No teacher laptop	93	.18	.09
Teacher laptop	116	.19	.04
Breadth of Experience			
Controlling for age	249	.34	<.01
Men	58	.44	<.01
Women	241	.31	<.01
0-4 computers	202	.31	<.01
5+ computers	100	.34	<.01
No teacher laptop	137	.34	<.01
Teacher laptop	165	.32	<.01

Note: Results for partial correlation report degrees of freedom instead of N.

Bivariate correlations were run separately for each of the two measures of technology use with students, controlling for age, gender, computer access in the classroom, and teacher laptop. An overview of the results of the analyses for the dichotomous variables is presented first, in table 5-6. All analyses are then examined below.

Age

Frequency. Partial correlation was used to explore the relationship between TPACK and frequency of computer use in class by students, while controlling for age. Preliminary analyses were performed to ensure that there were no violation of the assumptions of normality, linearity, and homoscedasticity. There was a strong partial correlation between TPACK and breadth of activities, controlling for age, $r = .26$, $df = 167$, $p < .01$, with higher TPACK related to more frequent computer use. An inspection of the zero order correlation ($r = .26$) suggested that controlling for age had no effect on the strength of the relationship between these two variables.

Breadth of activities. Partial correlation was used to explore the relationship between TPACK and breadth of activities with students, while controlling for age. Preliminary analyses were performed to ensure that there were no violation of the assumptions of normality, linearity, and homoscedasticity. There was a strong partial correlation between TPACK and breadth of activities, controlling for age, $r = .34$, $df = 249$, $p < .01$, with higher TPACK related to higher breadth of activities. An inspection of the zero order correlation ($r = .34$) suggested that controlling for age had no effect on the strength of the relationship between these two variables.

Gender

Breadth of activities. The relationship between TPACK and breadth of activities was statistically significant for both men and for women in this sample. However the relationship was stronger for men, $r = .44$, $n = 58$, $p < .01$, than for women, $r = .31$, $n = 241$, $p < .01$. TPACK confidence accounted for twice as much (18.9%) of the variability in breadth of activities for men as for women (9.6%), however the much smaller number of men participating in the study combined with the fact that they are underrepresented compared to the general teaching population suggest that this finding be interpreted with care.

Frequency. A Spearman correlation was computed for the relationship between TPACK self-rating and frequency of classroom computer use for men and for women. The relationship was statistically significant for men, $r = .48$, $n = 45$, $p < .01$, and approached significance for women, $r = .13$, $n = 161$, $p = .08$. TPACK confidence accounted for 23.0% of the variability in frequency of use for men, but less than 2% for women.

Classroom Computers

Bivariate correlations were run to examine the relationship between TPACK and each measure of technology use with students, separating respondents into two groups based on whether or not they reported having 5 or more computers available in the classroom.

Frequency. Spearman correlations were computed for the relationship between TPACK self-rating and frequency of classroom computer for teachers with 0-4 classroom computers, and for those participants with 5 or more. The relationship with frequency was not statistically significant for those teachers with fewer than 5 computers, $r = .12$, $n = 131$, $p = .17$ For those participants with 5 or more in the classroom, the relationship was not significant at the .05 level, however it approached significance, $r = .20$, $n = 78$, $p = .08$. TPACK accounted for 4% of the variability in frequency of student computer use.

Breadth of activities. The bivariate correlation between TPACK confidence and the number of different activities assigned to students was statistically significant both for teachers with fewer than 5 computers, $r = .31$, $n = 202$, $p < .01$, and for those participants with 5 or more in the classroom, $r = .34$, $n = 100$, $p < .01$.

Teacher Laptop

Bivariate correlations were run to examine the relationship between confidence in TPACK and each measure of technology use with students, separating respondents into two groups based on whether or not they reported having a teacher laptop available.

Frequency. Spearman correlations were computed for the relationship between TPACK self-rating and frequency of classroom computer for teachers with and without a teacher laptop. The relationship with frequency was statistically significant for those teachers with a laptop, $r = .19$, $n = 116$, $p = .04$, accounting for 3.5% of the variability in frequency. For those participants without a laptop the relationship was not significant at the .05 level, however it approached statistical significance, $r = .18$, $n = 93$, $p = .08$. For them, TPACK accounted for 3.2% of the variability in frequency of student computer use.

Breadth of activities. The correlation between TPACK confidence and the number of different activities assigned to students was statistically significant both for teachers with a laptop, $r = .32$, $n = 165$, $p < .01$, and for those participants without, $r = .34$, $n = 137$, $p < .01$.

Summary: Student Use

In these analyses, the participants' TPACK showed a robust relationship to the breadth of activities measure, in which they reported the number of types of activities they had asked students to engage in 3 or more times. The correlation continued to be significant when controlling for age, gender, classroom computers, and teacher laptop. The relationship of TPACK confidence with frequency of student use was less consistent. The correlation continued to be significant when controlling for age, and for men and for teachers with laptops. The relationship was less strong for women or teachers without laptops, although it trended in the same direction. The relationship between TPACK and frequency of computer use became meaningless however for respondents with low numbers of classroom computers.

Comparing the relationship between the self-reported TPACK scores and these two measures of student computer use helps to highlight the difference between the two. High technological pedagogical content knowledge (TPACK) is less relevant in the absence of classroom computers, when frequent computer use is the dependent measure. The less time-sensitive measure of activity exploration does not seem to require on-demand computer access to the same extent.

Chapter 5 Summary and Discussion

In this chapter I sought to answer the question, "What is associated with greater confidence in technological pedagogical content knowledge (TPACK)?" I began by arguing that the measures in this survey were reflective of confidence, rather than an objective assessment of knowledge. Because of the self-report nature of the survey, they are necessarily subjective. Given that these may be measures of confidence, what can we learn from these analyses?

One way to answer is to say what TPACK confidence is *not*: it is not the same as confidence in general technology knowledge (TK). In a variety of analyses TPACK confidence proved to be distinct from TK confidence. In an exploratory factor analysis, the items related to TPACK confidence loaded on a different factor than those associated with TK confidence. The distributions were different, with TK confidence showing a broader range of responses, and TPACK confidence showing more spikes and a tendency toward the high end of the scale. TPACK confidence related less strongly to general technology skills and pro-technology beliefs, and more strongly to beliefs valuing technology *for teaching*.

So does it mean to have confidence in TPACK? Different conceptual frameworks suggest ways to interpret the TPACK confidence measure, with implications for further research.

One interpretation of the relationship of TPACK confidence with more activities is that it taps an underlying willingness to attempt change. This perspective derives from the idea that assigning a broad range of activities over time requires the teacher to explore lessons that are novel. A positive orientation toward change has been found to relate to more frequent technology use (Player-Koro, 2007), but frequent student computer use is possible with relatively stable routines. Assigning a variety of computer activities to students may or may not translate into later stable routines; the emphasis in this measure is on the willingness to try.

A willingness to try may be seen as a reflection of self-efficacy expectations, "the conviction that one can execute the behaviors required to produce [a certain outcome]" (Bandura, 1977, p. 193). As Bandura explains, these expectations are different from outcome expectations in that they lead to behavior but not necessarily to outcomes. The fact that the relationship of TPACK confidence to frequency of student use lessens when teachers have too few computers in the classroom suggests that TPACK confidence may be at least partly independent of the actual ability to effect the desired outcome. Self-efficacy theory also identifies past mastery experiences as a powerful contributor to self-efficacy expectations; the finding that higher TPACK confidence relates to more past experience using computers with students supports the interpretation of TPACK as a self-efficacy measure. Applying this theoretical framework focuses attention on the barriers faced by teachers in attempting to apply their knowledge in observable outcomes.

Another potentially useful framework related to technology adoption is the Technology Adoption Model (Davis, Bagozzi, & Warshaw, 1989), which predicts that adoption is more likely when the *perceived ease of use* and *perceived usefulness* of a tool are both high. Given that teachers' TPACK scores were also related to their beliefs about technology's usefulness in teaching, future research might consider whether TPACK confidence is related to perceived ease of use (e.g., "I can teach lessons that appropriately combine mathematics, technologies and teaching approaches"), and TPC beliefs to perceived usefulness of new tools (e.g., "Technology provides better strategies for learning mathematics"). The relationship between knowledge, beliefs, and use is complex, and potentially important to technology implementation in schools. Other scholars have already observed the relationship between the importance of teachers' pedagogical beliefs and their choice of tools and practices (Becker, 2000; Ertmer, 2005; Hermans, Tondeur, Valcke, & van Braak, 2006; Zhao & Cziko, 2000). This framework highlights the importance of attending to not only knowledge, but also the extent to which beliefs impact or interact with the choice to acquire new knowledge, as an area for further study.

Finally, the difference between the relationships of TPACK confidence to the two measures of student use—frequency of computer use and breadth of activities attempted—suggest the exploration of TPACK confidence as an indicator of adaptive expertise. Adaptive expertise involves the ability to apply or develop skills in new situations and according to new constraints, and also judgment as to whether the new application of the skills is appropriate (Hatano & Inagaki, 1986). Because the products generated in production activities are often variable in topic, medium, and execution, assessing them requires a different, more flexible knowledge base on the part of the teacher. The tools used for different production activities may also impact planning, preparation, and classroom management, further challenging the teacher to adapt existing practices. Adapting effective teaching techniques to a variety of activities and tools requires flexibility, and also judgment. As expressed by respondent 287, "I'm not afraid to try things out BUT before I invest heavily in something, I need to see [t]hat it has meaningful impact for my kids, not just a wow device or something fun." This framework suggests that we consider how teachers' TPACK confidence ratings relate to their ability to develop skills and exercise judgment when confronted with novel tools, contexts, and implementation constraints.

Further work is needed to examine the relationship between the measure of TPACK confidence and objective assessments of knowledge. Several scholars are working on the challenge of defining what TPACK looks like objectively in observational studies (e.g., Harris, Grandgenett, & Hofer, 2010; Hughes, 2005; Krauskopf, Zahn, & Hesse, 2011; Meskill, Mossop, DiAngelo, & Pasquale, 2005; Mishra & Koehler, 2006; Niess, 2005). The challenge in survey studies is to measure knowledge objectively in a way that allows for wide-scale implementation. The knowledge needed to effectively use technology to support student learning varies greatly depending on the students' developmental stage, the subject and topic being taught, and the technological tool being used. In order to implement a survey that assesses TPACK for teachers in a variety of teaching contexts, the measure must be fairly abstract. In this survey, even though neither the specific technologies nor the disciplinary concepts are specified in these measures, the TPACK confidence statements are situated in the classroom and subject-specific contexts. The view of TPACK confidence as situated in context is supported by the relationship between TPACK confidence and the reported experiences of students – both frequency of computer use in class and the breadth of activities assigned to students increased with higher TPACK confidence ratings.

However, the relationship between TPACK confidence and student use measures was open to some influence by confounding factors. The relationship between TPACK confidence and frequency of student computer use became insignificant when analyzed separately for teachers with high and low levels of classroom computers. The relationship between TPACK confidence and student use, though significant for both, was stronger for men than for women. As males tend to be more confident about technology in general (Barron, 2004; Chen, 1987), this type of finding raises the question whether an individual's tendency to be more or less confident impacts their TPACK self-rating. In order to address these concerns, more work is needed.

One approach that might address the confidence issue is to include a measure of general confidence, not related to TPACK or its component domains, which could then be co-varied out in analyses. Responses of more-confident and less-confident individuals might then be more accurately compared. The hope would be that the remaining confidence would more accurately reflect the respondents' knowledge. To test that assumption however we still need to assess knowledge more objectively.

An approach that could address knowledge more directly while eliminating the confound of technology access would be to provide several standardized scenarios of potential technology use in teaching, asking respondents to imagine how they would plan the lesson and what outcomes they would expect. The open-ended responses could then be coded for evidence of knowledge related to technology, pedagogy, content, and their intersections. The goal of this research is to identify the ways in which teachers think about the constraints and opportunities related to the use of those technologies for effective teaching; ultimately, such measures will allow scholars to study the relationship of teachers' TPACK to student learning.

Chapter 6: Where the Teachers Taught and Learned

In this chapter I address the question of how teachers with different levels of confidence in their technological pedagogical content knowledge (TPACK; Mishra & Koehler, 2006) differ from one another in their teaching and learning contexts. This understanding provides insights into the conditions under which their confidence in their TPACK may have developed, and may inform the design of successful interventions. Teaching and learning contexts are explored at three levels: 1) school, 2) classroom, and 3) outside of school. The distinction between learning resources inside and outside of schools provides insights into the importance of support in different settings of a teacher's learning ecology, by which I mean the "the accessed set of contexts, comprised of configurations of activities, material resources and relationships, found in co-located physical or virtual spaces that provide *opportunities for learning*" (Barron, 2004, p. 6, emphasis added). Understanding how access to and perception of opportunities differ among teachers across their learning ecologies may spark a variety of insights into how we might help teachers acquire new skills and competencies.

Teaching Contexts

There are many indicators that suggest a relationship between TPACK and the school context. Good teachers consider the larger school context when making decisions in the classroom (e.g., Barnet & Hodson, 2001). In the area of computer use, prior studies have shown that students in schools in high- and low-SES communities may experience very different computer-based activities, even when access to computers itself is not an issue (Margolis, 2008; Warschauer & Matuchniak, 2010). It is possible that schools in high- and low-SES communities tend to attract teachers with different levels of TPACK, leading to the observed differences in instruction. It is also possible that teachers' knowledge of how to use technology to effectively support student learning is influenced, supported, or blocked by factors embedded in the school environment. By examining several school factors, we can begin to form hypotheses about the nature of the relationship between these factors and teachers' confidence in their TPACK.

To identify relevant classroom-level dimensions for analysis, I turn to the tripartite TPACK framework, which highlights the importance of attending to pedagogy and content, as well as technology, when exploring how teachers use new tools in the classroom. This framework suggests that use of technology in the classroom is related to not only the computers available, but also the students and the content being taught. Although there are ways to use new technologies to support learning of many subjects at all levels (AACTE, 2008), it may be that teachers of certain subjects or grade levels tend to have higher levels of TPACK than their colleagues. This study includes analyses of the differences among three profiles of TPACK in the subjects (content) they teach, grade levels and course target populations (pedagogy), and their levels of computer access (technology) in the classroom.

Learning Contexts

Previous studies have underscored the importance of considering multiple contexts for learning, as interest and knowledge developed in one setting may well be activated in another (Barron, 2004; 2006). Koehler and Mishra (2008) argue that teaching with computers is a “wicked problem” – one that involves a large number of dynamic, contextually bound, interdependent variables – which requires specialized knowledge. Because of the complexity of the challenge, the knowledge a teacher needs to acquire may be distributed among many different resources across multiple settings, each contributing to some aspect of technology applications, pedagogy, or content area concepts.

In addition to considering the resources themselves, it is interesting to consider where and by whom teachers are given access to them. Other studies have shown that key individuals within the school environment can play an important role in the implementation of innovations (Penuel, Riel, Krause, & Frank, 2009; Ryymin, Palonen, & Hakkarainen, 2008). Given the relevance of technology to various settings in teachers’ lives, it is possible that teachers develop TPACK at least in part through the support of learning partners outside of the pedagogical context. The question becomes whether teachers with higher TPACK confidence levels have more supporters and access more types support in personal contexts outside of the school or district, and whether they have more support within the professional settings of the school or district. Knowing which supporters in which settings provide access to resources has implications for the design of professional learning experiences for teachers. This study included an opportunity for respondents to list all the individuals who support their learning to use technologies for teaching. Recognizing the importance of these *learning networks* in providing access to knowledge provides a different way of exploring the different ways in which TPACK confidence may develop.

Finally, the role of new technologies in facilitating teacher learning is tied to both learning ecologies and learning networks. A mobile computer can move from setting to setting, such as from school to home or from one classroom to another. This movement across settings has the potential to facilitate access to a broader range of learning supporters, leading to more social and human capital. Flexibility of time and place are important; Americans' use of the Internet for "capital-enhancing activities" such as health-information seeking and online banking has been linked to the freedom to use computers when and where one wants to (Hargittai, 2010; Hassani, 2006). Whether the participant takes the computer home or to the classroom next door, in many cases the mobility of the tool may permit a teacher to access the just-in-time assistance of teaching colleagues, IT support, content experts, friends, or family members in ways not possible with a desktop computer. It may allow activities such as exploration, setup time, and practice outside the classroom. Through increased access to learning supporters, we would expect that laptops would facilitate teachers' development of confidence and knowledge of how to use technology to support student learning.

Organization of the Chapter

In part 1 of this chapter I examine the relationship of TPACK confidence profiles to the larger context of the school. In addition to indicators of student SES, I also examine school identifiers such as whether the school is identified as high achieving by the state or is receiving assistance, and whether it is a regular public school. I also consider the relationship of TPACK confidence profile to the availability of computers for student use in the school. In part 2 of this chapter I examine variables describing the classroom context, including grade level taught, subject area discipline, course target population, and the level of computer access in the classroom. Finally, in part 3, I turn to factors outside of the school context that may provide insights into the context of teachers with different levels of self-reported TPACK. I examine the number of learning resources and supporters they have outside of the school context, their access to a teacher laptop, and teachers' use of the Internet for teaching ideas. Together school, classroom, and out-of-school context descriptors give important insights into how teachers with different levels of TPACK confidence differ in their teaching and learning contexts.

For each part of this chapter, the relevant measures are presented first, followed by the analyses. Each part of this chapter ends with a summary of findings and their implications. A discussion of the findings across all three parts concludes the chapter.

Part 1: School and Community

In this section I examine the relationship of the teachers' TPACK confidence profile to the characteristics of the school and community context, including state recognition, neighborhood, public or not, percent of students who are low-income, school-based resources for learning about teaching with technology, and the number of computers available for student use.

Measures: School and Community

TPACK Confidence Profile

Respondents rated their technological pedagogical content knowledge (TPACK) on 5 items, which were averaged for each subject area taught. The highest TPACK self-rating across subjects for any respondent became the TPACK confidence score. Averaged scores ($N = 307$) ranged from 1 to 5. The distribution was negatively skewed, with a mean of 3.91 and a standard deviation of .80. For a full discussion of the TPACK confidence measure, please see Chapter 5.

The distribution was examined visually to determine if there were natural break points between groups of respondents. The distribution followed a normal curve with the exception of two spikes in the distribution: one at 5.0 (the maximum), and another at 4.0. Because 4.0 corresponded to "agree" on the individual items, it was meaningful to distinguish between teachers whose average was less than agree, agree, or more than agree. The number of respondents whose average was above 4.0 (96, or 31.3%) was roughly equal to the number whose average equaled 4.0 (87, or 28.3%), with slightly a higher number (124, or 40.4%) averaging less than 4.0. These groups were labeled high-TPACK, mid-TPACK, and low-TPACK, respectively.

State Classification

High-achieving. Participants were asked to indicate whether their school was "Recognized by the state as a successful school (Distinguished / Blue Ribbon / AAA)." These were coded as *high achieving* schools; 26.9% of 305 respondents indicated they worked at such a school.

Receiving assistance. Participants were asked to indicate whether their school was "Receiving assistance to improve student achievement (Program Improvement / State Monitored / High Priority)." These were coded as schools *receiving assistance*; 41.6% of 305 respondents indicated they worked at such a school.

Title 1. Participants were asked to indicate whether their school was "Title 1 (at least 40% of students in the free and reduced lunch program)." These were coded as *Title 1* schools; 63.6% of 305 respondents indicated they worked at a Title 1 school.

Public

Participants were asked to choose the best description of their school from public, magnet, charter, private, or other. The 304 responses were collapsed to public (89.4%) and other (10.6%).

Neighborhood

Participants were asked to choose a description of "the area where your school is located." The 306 responses were collapsed to inner city (23.2%), urban (32.0%), suburban (34.0%) and other, which included small town, rural, and none of the above (10.8%).

Percent Low-Income

In a constant-sum survey item, participants were asked to indicate what percentage of students in the community served by their school were affluent, average, or low-income. The three variables were constrained to add up to 100%. For these analyses, I focus on the percentage of low-income students reported by participants. The reports by the 307 respondents in this study ranged from 0 to 100, with a mean of 60.59 (*SD* = 31.34). The 25th percentile included populations up to 33%, the 50th percentile up to 70%, and the 75th percentile up to 89% low-income.

Number of Computers at School

Participants were asked about their school: "What kinds of digital technology can you sign up for or check out, to use with students? (Check all that apply.)". Although many types of equipment were listed, in these analyses I focus on the responses relating to the number of computers.

Responses suggested that some participants may have duplicated the responses from the question asking about computers available "in your classroom or where you teach," especially when considering mobile computers. Therefore a set of variables was created, discounting potential duplicates and keeping only the number that the respondent had clearly reported was available to them either in the classroom or for checkout. Where the presence of computers was not clearly indicated, they were coded as not present.

To further guard against false findings, the continuous numbers reported for these items were recoded to reflect three levels of access across both items. The dichotomous variables reflected whether at least 20, 40, and 60 computers were available anywhere in the school. The higher levels included the lower levels of access. Thus a respondent reporting 50 computers would be coded as having 20 and 40, but not 60 computers. By these conservative numbers, a majority (70.4%) of the 307 participants reported having at least 20 computers available to use with students, 30.3% reported at least 40, and 12.4% reported at least 60 computers somewhere in the school.

Learning Resources

Separate parts of the survey gathered information about resources that were *available* to the participants, and those that they considered *important* to learning to use new technologies for teaching.

Available resources. Participants were asked, "What resources are available in your school or district to support your own learning about technology? (Check all that apply. You do not have to have used them, but if you believe they are available to you, please mark them.)" Resources on the list included items relating to professional development, publications, and online resources. The eight resources were tallied to create a *breadth of available resources* variable. Scores for 301 participants ranged from 0 to 8, with a mean of 2.53 (SD = 2.03) and a mode of 2.

Important resources. In addition to what resources were *available*, participants were asked what resources were *important* to their learning. The measures of *important* resources appeared several screens after the *available* measure above. Participants responded to the prompts "Which of the following are important resources in your school or district that support your learning how to use new technologies for teaching? (Check all that apply. Check only if this resource supports your use of technology for teaching.)" This question was followed by a list of resources. Ten items relating to professional development, publications, and online resources were on the list. It included the 8 items from the list of available resources, added teaching profession publications, and split the item asking about an online network into two: related to technology, and "other school or district-based online network." The important resources inside the school/district were tallied to create an *important school resources* variable. Scores for 307 respondents ranged from 0 to 9, with a mean of 2.08 (SD = 1.73) and a mode of 2. Table 6-1 presents the items tallied in the *available* and *important* resources variables.

Learning Supporters

Number of supporters. Survey participants were asked to list important people who support their learning of technology for teaching, and each person's relationship to the participant. The survey provided a series of 8 empty fields and asked respondents to provide code names or initials for each learning supporter. A second page of 8 blanks was available on request, for a total possible of 16 people who supported their learning to use technology for teaching. The total number of people listed became the *number of learning supporters.* The number of learning supporters ranged from 0 to 11, with a mean of 2.70 (*SD* = 1.88).

Table 6-1. List of items measuring available and important resources for learning to teach with technology.

Resource	Available	Important
Technology-related workshops/classes at my school or district	✓	✓
Other forms of Prof. Dev. which include technology	✓	✓
Teaching profession publications		✓
Teaching with Technology publications	✓	✓
Technology books or manuals	✓	✓
Technology Magazines	✓	✓
Rec's for online articles, blogs, discussion threads, etc.	✓	✓
Step-by-step tutorials /instructions by school or district personnel	✓	✓
School- or District-based online network related to technology		✓
(Other) School- or district-based online network	✓	✓

Amount of support. Nine different ways in which learning supporters might facilitate the learning of participants were listed. The types of support were based on prior work with adolescents, which examined the roles of parents in supporting interest development (Barron, Martin, Takeuchi, & Fithian, 2009). Roles included for example teaching, sharing a vision, collaborating, and funding equipment purchases. For each learning partner, participants indicated the nature of the support each person provided, by checking all the types that applied. The tally of all the kinds of support provided for each participant across all learning supporters became the *amount of support* score. Note that the same type of support may have been provided by multiple supporters, and is counted once for each time it was checked. Thus the maximum 11 learning supporters could in theory provide 99 instances of support. The tallies ranged from 0 to 55, with a mean *amount of support* score of 7.31 (*SD* = 7.69).

School setting. Participants were also asked to choose the best description of the relationship of each learning supporter. Based on the relationship, each supporter was classified as available within the school or not (including district office, other schools, home, outside, or unknown). New continuous variables were created to examine both the number of *school learning supporters* and the amount of *school support*. The average number of school learning supporters (including colleagues, administrators, technology mentors, tech support, students, and parents) was 1.70 (SD = 1.38) with a mode of 1. The average amount of school support was 4.53 (SD = 5.18) with a mode of 0.

Analyses: School and Community

State Classification

High-achieving. Slightly more mid-TPACK teachers (32.2%) reported that they taught at a school identified as high achieving by the state, than high-TPACK (24.2%) and low-TPACK (25.2%) teachers. However, the difference was not statistically significant (χ^2 (2, N = 305) = 1.77, p = .41).

Receiving assistance. Teachers in the three TPACK confidence profiles were equally likely to report that they taught at a school identified by the state as needing improvement (χ^2 (2, N = 305) = .21, p = .90), with 41.1% of high-TPACK teachers, 43.7% of mid-TPACK teachers, and 40.7% of low-TPACK teachers reporting that they worked in a school that was receiving assistance to improve student achievement.

Title 1. Although slightly fewer high-TPACK teachers reported that they taught in Title 1 schools (58.9%) than mid-TPACK (66.7%) or low-TPACK (65.0%), the difference was not significant (χ^2 (2, N = 305) = 1.35, p = .51).

Percent Low-Income

A one-way ANOVA examined whether the percent of low-income students in the school differed by TPACK confidence group. Results indicated that there were no significant differences between profiles, F (2, 304) = .33, p = .72 On average, high-TPACK teachers reported 59.5% low-income students (SD = 31.20), mid-TPACK teachers 62.9% (SD = 31.91), and low-TPACK teachers 60.0% (SD = 31.21). As indicated by the standard deviations, there was large variability within each group.

Public

Overall, 89.4% of respondents reported that they taught in a school best described as public. Although slightly more high-TPACK teachers (13.7%) taught in schools they identified as private, charter, magnet, or other, than low-TPACK teachers (8.1%) and mid-TPACK teachers (10.6%), the difference was not statistically significant (χ^2 (2, N = 303) = 1.75, p = .42).

Neighborhood

The percentages of respondents in each of the three TPACK confidence profiles who reported they worked in a school in an inner city, urban, suburban, or other type of neighborhood were not significantly different (χ^2 (6, N = 306) = 1.02, p = .99). The percentages are presented in table 6-2.

Number of Computers at School

To examine whether teachers in the three TPACK confidence profiles differed in the availability of computers for student use at their schools, separate Chi-square analyses

Table 6-2. Percentage of respondents working in different neighborhood environments

	TPACK		
	Low	Mid	High
Inner city	25.0	20.9	22.9
Urban	30.6	32.6	33.3
Suburban	33.9	33.7	34.4
Other	10.5	12.8	9.4

were run with the three levels of access anywhere in the school. As seen in table 6-3, teachers in the low-TPACK group were significantly less likely to report that they had 40 or more computers available for student use, than their mid- and high-TPACK colleagues. The same pattern was repeated at much lower rates at the level of 60 or more computers. Far more respondents reported having 20 or more computers available; at this level the mid-TPACK teachers reported the highest access.

Table 6-3. Percentage of respondents with levels of computer availability in school

	TPACK				
	Low	Mid	High	χ^2	*p*
20 or more	66.9	79.3	66.7	4.67	.10
40 or more	21.8	34.5	37.5	7.35	.03
60 or more	8.1	13.8	16.7	3.92	.14

Learning Resources Available

A one-way ANOVA examined whether the total number of different resources available at school to support teachers' learning to use technology varied by TPACK confidence group. Results indicated that there were differences between profiles, F (2, 298) = 8.41, $p < .01$. Post-hoc analysis using Tukey's HSD indicated a split between the high-TPACK teachers and the other two groups; they reported a higher average number of available resources (M = 3.21, SD = 2.20) than the mid-TPACK teachers (M = 2.35, SD = 1.84) and low-TPACK teachers (M = 2.13, SD = 1.89).

Important Learning Resources

A one-way ANOVA examined whether teachers in the three TPACK confidence profiles differed in the number of different learning resources at school they considered important. Results indicated that there were differences between profiles, F (2, 304) = 5.73, $p < .01$. Post-hoc analysis using Tukey's HSD indicated significant differences between the high-TPACK teachers (M = 2.56, SD = 1.83) and the low-TPACK teachers (M = 1.79, SD = 1.65); the difference between high- and mid-TPACK teachers (M = 2.00, SD = 1.63) approached statistical significance (p = .07).

Important and Available Resources

Although most respondents who indicated a school-based resource was important had also marked it as available, one-third (103) of respondents marked at least one resource important but not available at school. Almost half (140) respondents marked the two items identically, raising questions about how the teacher decided that this would be an important resource. This will be addressed in the discussion.

Number of Learning Supporters

To examine whether the number of supporters identified by participants differed by TPACK confidence level, a one-way ANOVA was run with TPACK confidence group as the factor and total number of supporters as the dependent variable. A significant difference appeared between groups, F (2, 304) = 3.60, p = .03. Post-hoc analyses using Tukey's HSD showed that the high-TPACK teachers reported a significantly higher average number of supporters (M = 3.11, SD = 2.29) than the mid-TPACK teachers (M = 2.48, SD = 1.65). The difference between high- and low-TPACK teachers (M = 2.52, SD = 1.60) approached statistical significance (p = .06).

Total Amount of Support

Though the difference in number of supporters was relatively small, the difference in amount of support provided by those supporters was larger. A one-way ANOVA examined whether the amount of support provided by learning supporters differed by TPACK confidence group. Results indicated that there were differences between profiles, F (2, 304) = 5.76, p < .01. Post-hoc analysis using Tukey's HSD indicated significant differences between the high-TPACK teachers and the other two groups; they reported a higher average amount of support (M = 9.48, SD = 10.50) than the mid-TPACK teachers (M = 6.45, SD = 5.82) and low-TPACK teachers (M = 6.23, SD = 5.73).

Learning Supporters at School

To examine whether the number of supporters within the school setting differed by TPACK confidence level, a one-way ANOVA was run with TPACK confidence group as the factor and number of school supporters as the dependent variable. The number of school supporters was not significantly different between the three groups, F (2, 304) = 1.16, p = .32. On average, high-TPACK teachers reported 1.86 learning supporters at school (SD = 1.60), mid-TPACK teachers 1.56 (SD = 1.38), and low-TPACK teachers 1.66 (SD = 1.19).

School Support

A one-way ANOVA examined whether the amount of support provided by learning supporters in the school setting differed by TPACK confidence group.

Results indicated that there were marginally significant differences between profiles, $F(2, 304) = 2.98$, $p = .05$. However, post-hoc analysis using Tukey's HSD indicated that high-TPACK teachers' school support was higher than the other two groups at the .10 level. On average, high-TPACK teachers reported an average amount of support provided by supporters at school of 5.58 ($SD = 6.45$), with mid-TPACK teachers averaging 3.93 ($SD = 4.25$), and low-TPACK teachers 4.13 ($SD = 4.55$).

Summary: School and Community

The three groups of teachers defined by their self-rating of their technological pedagogical content knowledge (TPACK) did not differ on several dimensions related to their school and community teaching context. The groups did not differ meaningfully in the percent of respondents who indicated that the school they taught in was high achieving, receiving assistance, or Title 1. No significant differences appeared in the percent of students who were low-income, or whether the school was a regular public school. The neighborhood in which the school was located—inner city, urban, suburban, or other—did not vary significantly by TPACK confidence profile. These analyses consistently showed that these descriptors of the teaching context did not relate to respondents' level of TPACK. This is consistent with the TPACK framework, which suggests that TPACK, although varied by technology, content, and learner characteristics, exists across multiple subject and student contexts.

Several other variables, arguably easier to impact, did show a relationship to TPACK confidence level. A significant difference appeared between groups as to whether there were 40 or more computers available for student use at the school. Although the percentages of respondents indicating they had 60 or more computers available were much lower, the trend continued for higher TPACK teachers to be more likely to report higher levels of computers. Only at the 20+ level, which was far more common than the higher levels, showed a different pattern; there the mid-TPACK teachers reported the highest levels of access to computers, though the trend was not statistically significant.

The high-TPACK teachers reported higher numbers of resources available to them in the school setting for learning to teach with technology, and also nominated a higher number of important resources. The differences between groups in material resources for learning were mirrored in the number of people who supported their learning to teach with technology. Overall, high-TPACK teachers tended to list more learning supporters, and although the difference was not statistically significant, the difference in amount of support provided by those supporters was significant. The trends inside the school setting echoed the overall trends for high-TPACK teachers to report more learning resources and more support, though to a lesser extent.

Part 2: Classroom

In this section I examine the relationship of the teachers' TPACK confidence profile to the characteristics of the classroom, including grade level and subject area taught, course target population, and the availability of classroom computers.

Measures: Classroom

Grade Level

Participants in this survey were asked what grades they currently taught at their schools. Thirty-eight respondents reported teaching assignments that spanned more than one level across Kindergarten to 12th grade. In order to be able to compare across levels, a *lowest grade level* variable was created based on the lowest grade taught, following the common convention of primary (Kindergarten - grade 2), upper elementary (grades 3 - 5), middle (grades 6 - 8), and high school (grades 9 - 12). Fifteen respondents reported that they taught at the post-secondary level, taught teachers, or provided instructional or curricular support to teachers. Of these 15, all but 4 also taught K-12 students; those 4 were not included in analyses of grade level.

This coding led to classification of 75 (24.7%) participants as primary, 62 (20.4%) upper elementary, 59 (19.4%) middle, and 108 (35.5%) high school teachers. Similarly, a *highest grade level* variable was created based the highest grade taught in K-12; this coding led to classification of 52 (17.1%) participants as primary, 83 (27.3%) upper elementary, 58 (19.1%) middle, and 111 (36.5%) high school teachers.

Subject

Respondents were asked to identify "the subject(s) you are teaching for your main assignment this year" from a list. Many teachers selected multiple subjects. As it is not possible to identify a primary subject from this data set, it is inappropriate to use this list to compare teachers of one subject with teachers of another. Instead, teachers of each subject are compared to all teachers who don't teach that subject. Subsequent analyses compare teachers with different national board certification areas, which combine subject and level.

Overall, 55% of respondents indicated they currently taught English/Language Arts, 46% taught Math, 43% taught Science, and 40% taught Social Studies. For the purposes of these comparisons, I focused on the core academic subjects; otherwise limits on the number of family-wise comparisons would make it very difficult to find a significant effect.

To examine the idea that accomplished teachers in different subjects and levels might tend to rate their TPACK differently, I turn to the participants' area of national board certification. Although some participants may not currently be teaching in the area of their certification, this measure is presumed to reflect a primary affiliation with a subject and level. Twenty-four certifications were represented in the data set, and for the purposes of analysis were collapsed as follows. Teachers with Early Adolescence and Adolescence through Young Adulthood certificates, were combined within subject area to provide greater statistical power. Thereafter, any certificate represented with 10 or more NBCTs was kept as a separate group; all others were coded as "other." This categorization resulted in 53 Early Childhood Generalists (17.3% of participants), 40 Middle Childhood Generalists (13.0%), 13 certified in Early and Middle Childhood/ English as a New Language (4.2%), and 15 in Early and Middle Childhood/ Literacy: Reading-Language Arts (4.9%). At the Early Adolescence and Adolescence through Young Adulthood levels, 47 were certificated in English Language Arts (15.3% of study participants), 24 in Mathematics (7.8%), 28 in Science (9.1%), and 16 in Social Studies – History (5.2%). An additional 20 participants (6.5%) were certified as Exceptional Needs Specialists, Early Childhood through Young Adulthood.

Course Target Population

Participants were asked about the target populations of their courses: "This question is about your courses, not the students. For example, if you teach a regular education course with some ELL students, check regular education." When asked to describe the courses they taught, 28.7% of participants reported that they taught courses for advanced students (AP / IB / Pre-IB / Honors / GATE), while 14.9% taught remedial courses. Thirty-five percent taught courses designated for English language learners. Almost one respondent in 7 (13.9%) taught a course designated as special education, and 81.5% taught regular education courses. Because one teacher may teach several types of courses, these numbers add up to more than 100%.

Computers in Classroom

Participants were asked to indicate the number of desktops and laptops available to them "in your classroom or where you teach." The combined number of desktop and laptop computers ranged from the mode of 0 to a maximum of 175. The range of responses suggests a variety of interpretations of the phrase "where you teach;" therefore using the full continuous variable was inappropriate. To minimize the risk of comparing teachers with classroom computers to those counting computers outside the classroom, while still honoring the fact that the respondents did consider these computers accessible, a minimum threshold number was used instead. Becker (2000) showed that teachers with 5 or more computers in the classroom were more likely to use computers more frequently with students. Therefore two dichotomous variables were created from this range: *any classroom computer* and *5+ classroom computers*. These reflect two levels of access: those who had at least 1 computer available "where they teach," and a higher level reflecting those who had at least 5 (which includes the lower level). In this sample, 74.6% of respondents had at least 1 computer, and 33.2% of respondents reported having at least 5 computers available "where they teach."

Analyses: Classroom

Grade Level

In order to examine whether teachers in each of the three TPACK confidence profiles differed by the grade levels taught, two Chi-square analyses were performed. The first grouped the respondents by lowest grade taught, the second by the highest grade taught.

Lowest grade level. The percentages of respondents in each of the three TPACK confidence profiles who reported that their current teaching assignment included grades K-2, 3-5, 6-8, or 9-12 were not significantly different (χ^2 (6, N = 304) = 2.91, p = .82). The percentages are presented in table 6-4.

Table 6-4. Percentage of respondents in each TPACK confidence group who reported they taught in that level (based on lowest grade)

	TPACK		
Level	Low	Mid	High
K-2	27.4	21.2	24.2
3-5	20.2	21.2	20.0
6-8	21.0	21.2	15.8
9-12	31.5	36.5	40.0

Highest grade level. Similarly to the previous analysis, the percentages of respondents in each of the three TPACK confidence profiles who reported teaching at each level, based on the highest grade they currently taught, were not significantly different (χ^2 (6, N = 304) = 3.67, p = .72). The percentages are presented in table 6-5.

Table 6-5. Percentage of respondents in each TPACK confidence group who reported they taught in that level (based on highest grade)

	TPACK		
Grade Level	Low	Mid	High
K-2	17.7	15.3	17.9
3-5	29.0	27.1	25.3
6-8	21.8	20.0	14.7
9-12	31.5	37.6	42.1

Subject

Individual subjects. To examine whether teachers in the three TPACK confidence profiles differed in the subjects they taught, Chi-square analyses were run individually for four core academic subjects. As opposed to the analyses above, these did not compare across subject area, but only within. The percentages of teachers in each profile who taught each subject were not significantly different (see Table 6-6).

Table 6-6. Percentage of respondents in each TPACK confidence profile reporting that they taught the subject

	TPACK				
Subject Area	Low	Mid	High	χ^2	p
English/Language Arts	50.8	59.8	56.3	1.74	.42
Math	46.0	47.1	45.8	.04	.98
Science	41.1	41.4	49.0	1.60	.45
Social Studies	35.5	42.5	42.7	1.57	.46

Comparisons across subjects. In order to compare across subject areas, respondents were analyzed based on the area of their National Board certification. The percentages of respondents in each of the three TPACK confidence profiles who held each of 10 certificates were not significantly different (χ^2 (18, N = 307) = 14.57, p = .69). The percentages are presented in table 6-7.

Table 6-7. Percentage of respondents in each TPACK confidence group holding each National Board Certificate

	Low	Mid	High	Total
Early Childhood Generalists	18.5	12.6	19.8	17.3
Middle Childhood Generalists	11.3	16.1	12.5	13.0
Early and Middle Childhood				
English as a New Language	5.6	4.6	2.1	4.2
Literacy: Reading-Language Arts	6.5	4.6	3.1	4.9
Early Adolescence & Adolescence - Young Adulthood				
English Language Arts	12.1	19.5	15.6	15.3
Mathematics	8.1	10.3	5.2	7.8
Science	7.3	6.9	13.5	9.1
Social Studies – History	4.0	6.9	5.2	5.2
All Ages: Exceptional Needs Specialists	8.1	5.7	5.2	6.5
Other	18.5	12.6	17.7	16.6

Course Target Population

Respondents were asked what types of courses they taught. To examine whether teachers in the three TPACK confidence profiles differed in their course target populations, Chi-square analyses were run individually comparing the percent of teachers who taught 5 types of courses: advanced, remedial, English Language Learners, Special Education, and regular education. Again, these analyses compared teachers who taught or did not teach each type of course, without comparison to the other groups. As seen in table 6-8, teachers in the mid-TPACK group were significantly more likely to report that they taught courses to advanced students, than their mid- and high-TPACK colleagues. This effect was significant even with a Bonferroni adjustment to the alpha level, to allow for the multiple family-wise comparisons. A similar trend appeared among teachers of courses targeting remedial students, though the difference was not statistically significant.

Table 6-8. Percentage of respondents teaching courses for target student populations

	TPACK				
	Low	Mid	High	χ^2	p
Advanced	22.1	41.2	12.3	9.37	<.01
Remedial	12.3	21.2	12.5	3.74	.15
English Language Learners	32.8	32.9	39.6	1.31	.52
Special Education	12.3	12.9	16.7	.94	.62
Regular Education	77.9	83.5	84.4	1.83	.40

Computers in Classroom

Respondents were asked how many computers were available "in the classroom or where you teach." Two variables were created: whether there were any computer in the classroom for student use, and whether there were 5 or more. Chi-square analyses were run comparing the three TPACK confidence profiles on these two variables.

Any computer for checkout. No significant differences appeared between the three TPACK confidence groups in the percentage of teachers who had at least one computer available for student use by reservation (χ^2 (2, N = 307) = 3.43, p = .17).

The majority of teachers in all three groups reported that they had at least one; 69.8% of high-TPACK teachers, 82.6% of mid-TPACK, and 75% of low-TPACK teachers reported a minimum level of access. The remaining teachers did not report having any computers available for checkout.

Any computer in the classroom. Significant differences appeared between the TPACK confidence groups in the percentage reporting at least one computer available in the classroom for student use (χ^2 (2, N = 307) = 10.34, p < .01). Roughly two-thirds of low-TPACK teachers (65.3%) reported one or more computers, as compared to three-fourths (77.0%) of mid-TPACK teachers, and over five-sixths (84.4%) of high-TPACK teachers.

5+ computers. Far fewer teachers reported having 5 or more classroom computers. Significant differences appeared between the TPACK confidence groups in the percentage reporting 5 or more computers available in the classroom for student use (χ^2 (2, N = 307) = 12.29, p < .01). Fewer than one in four low-TPACK teachers (23.4%) reported the higher level of computer access, as compared to one in three (33.3%) mid-TPACK teachers, and almost one in 2 (45.8%) high-TPACK teachers. Figure 6-1 shows the relative availability of computers for each TPACK group.

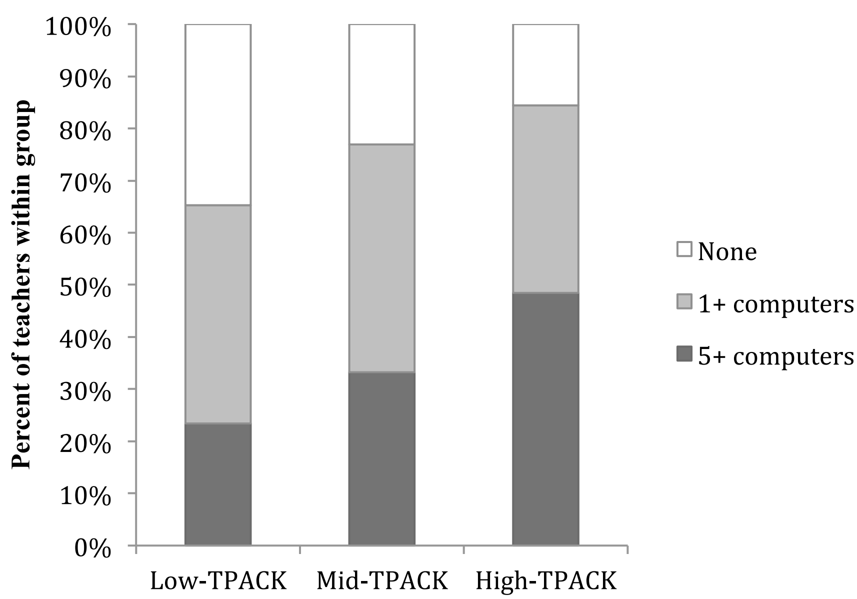

Figure 6-1. Percent of teachers with no, 1+, and 5+ computers in the classroom within each TPACK confidence group. A significant trend appears in the number of teachers with 1 or more, and with 5 or more computers in the classroom.

Summary: Classroom

In this section I examined the relationship of the teachers' TPACK confidence profile to the characteristics of the classroom context, including grade level and subject area taught, course target population, and the availability of classroom computers. The findings for the classroom context echoed those of the school and community analyses, in that the most inalterable factors – grade level taught, subject taught, and course target population – were not significantly different for teachers within the three TPACK confidence groups. The only exception was teaching courses for advanced students, which was significantly more common among mid-TPACK teachers. Whether this is due to some characteristic of the students in such courses, the nature of teachers who teach them, or the curriculum itself is unknown. This may be an interesting area for future study. The responses of mid-TPACK teachers will be addressed again in Chapter 8.

As in the preceding school-wide analyses, computer access in the classroom showed a relationship to TPACK confidence level. Although having 1 or more computers was common for the three profiles, between 35% (low-TPACK) and 16% (high-TPACK teachers reported that they had no computer for students to use in the classroom or where they taught. A significant difference appeared between groups as to whether there were both 1 or more, and 5 or more computers available for student use in the classroom; high-TPACK teachers were more likely to have the higher level of access. This aligns with Becker's (2000) finding that teachers with 5 or more computers in the classroom are more likely to give their students frequent opportunities to use computers. Mirroring the classroom findings at the school-wide level, the high-TPACK teachers were more likely to report 40 or more computers available for student use. The correlational nature of these findings prevent me from drawing conclusions about whether higher TPACK teachers advocate for, or even provide themselves with, the computers in the classroom, or whether the constant availability of computers to use with students support the development of TPACK. The relationship is an interesting one however, and its implications for policy deserve further exploration.

Part 3: Outside of School

In this section I examine the relationship of the teachers' TPACK confidence profile to the learning resources they have access to outside of the school context. These include learning resources such as workshops and publications, offsite learning supporters and the support they provide, laptops, and use of the Internet for teaching ideas.

Measures: Outside of School

Important Learning Resources Outside of School

Respondents were asked to choose from a list the important resources outside of the school or district that supported their learning to use technologies in school. Tallies of the 12 resources such as workshops, publications, or online networks ranged from 0 to 12, with a mean of 3.09 (SD = 2.34) and a mode of 2. For a full list of the items on the list, please see the full list of measures in Appendix A.

Offsite Learning Supporters

Survey participants were asked to list important people who supported their learning of technology for teaching. Those learning supporters who were identified by their relationship to the respondent as not being in the school setting were summed to create an *offsite supporters* variable. These supporters included district personnel, colleagues at other schools, spouse, family members, friends, product technology support, and unknown. The number of offsite supporters ranged from 0 to 7, with a mean of 1.00 (SD = 1.19) and a mode of 0.

Participants indicated which of 9 different types of support were provided by each offsite learning supporter, and the support provided across all supporters was summed to create a *offsite support score*. The total amount of support that was provided by offsite supporters ranged from 0 to 33, with a mean of 2.78 (SD = 4.15) and a mode of 0.

Laptop

Because a mobile computer can be taken away from the school site, I considered it a special kind of computer that might provide opportunities for learning across settings. The number of participants who reported that they had a "teacher computer (laptop)" was coded yes/not reported. Roughly half (54.6%) of the respondents indicated that they have a teacher laptop. I do not know whether the school or the respondent provided it. Of the respondents *without* a laptop for teaching, 75% reported that they do have a desktop computer to use for teaching; 11.4% of respondents did not report having either type of teacher computer available in the classroom or where they taught.

Use of the Internet for Teaching Ideas

A measure of the frequency with which respondents got inspiration for teaching online was included in the follow-up survey sent to respondents. Based on an item in the MetLife Survey of the American Teacher (Markow & Cooper, 2008), participants were asked "How often have you used an Internet resource to get teaching ideas?" Of the 211 study participants who responded to this item on the follow-up survey, 63.5% indicated that they use the Internet once a week or more, while the rest indicated that they used it less than once a week.

Analyses: Outside of School

Important Learning Resources Outside of School/District

A one-way ANOVA examined whether number of different important learning resources in the school differed by TPACK confidence group. Results indicated that there was a significant differences between profiles, F (2, 304) = 17.00, $p < .01$. On average, high-TPACK teachers reported 4.08 different resources outside the school/district context (SD = 2.57), which was significantly more than either mid-TPACK teachers 2.99 (SD = 2.13), or low-TPACK teachers 2.40 (SD = 1.77).

Learning Supporters Outside of School

To determine the extent to which the number of offsite supporters nominated by respondents varied by TPACK confidence group, a one-way ANOVA was run with TPACK confidence profile as the factor and number of offsite supporters as the dependent variable. Results indicated that there were significant differences by profile, F (2, 304) = 3.29, p = .04. Post-hoc analyses using Tukey's HSD showed that on average, high-TPACK teachers reported significantly more offsite supporters (*M* = 1.25, *SD* = 1.38), than low-TPACK teachers (*M* = .85, *SD* = 1.06). Mid-TPACK teachers reported an average of .92 (*SD* = 1.11) offsite learning supporters, which was not significantly different from the other two groups.

Learning Support Outside of School

A one-way ANOVA was run to determine the extent to which the amount of support provided by offsite learning supporters varied by TPACK confidence group. Results indicated that there were significant differences by profile, F (2, 304) = 5.00, $p < .01$. Post-hoc analyses showed that high-TPACK teachers reported significantly more offsite support (*M* = 3.82, *SD* = 5.66) than low-TPACK teachers (*M* = 2.10, *SD* = 2.87). Mid-TPACK teachers were not significantly different from either of the other groups (*M* = 2.52, *SD* = 3.44).

Laptop

A Chi-square analysis explored whether teachers in the three TPACK confidence profiles differed the prevalence of a teacher laptop. Teachers in the low-TPACK group were significantly less likely to report that they had a teacher laptop (42.7%), than their mid-TPACK (60.9%) and high-TPACK (65.6%) colleagues (χ^2 (2, N = 307) = 13.14, $p < .01$).

Use of the Internet for Teaching Ideas

Chi-square analyses were also used to examine whether teachers in the three TPACK confidence profiles differed in the frequency with which they turned to the Internet for teaching ideas. More teachers in the high-TPACK group reported that they did so at least once a week (75.4%) than their mid- (69.5%) and low-TPACK (50.6%) colleagues; the difference was statistically significant (χ^2 (2, N = 211) = 11.15, $p < .01$).

Summary: Outside of School

The analyses in Part 3 examined whether teachers in each of the three TPACK confidence profiles differed in their access to learning resources outside of the school context. These included material resources, learning supporters and the support they provided, autonomous computing in the form of a teacher laptop, and use of the Internet for teaching ideas. Continuing the trend of school and classroom contexts, significant differences appeared between profiles in their access to outside learning resources, with the high-TPACK teachers reporting more different resources, more supporters providing more support, and higher likelihood of having a laptop computer than the other two groups. The only exception was the measure of Internet access for teaching ideas. Even though not statistically significant, the tendency was for high-TPACK teachers to report more frequent use of the Internet for teaching ideas, a trend in the same direction as the other variables.

Chapter 6 Summary and Discussion

A strong pattern across school, classroom, and outside contexts in the analyses above showed that teachers in the three different TPACK confidence profiles differed significantly on variables related to learning to use technology for teaching. They did not, however, differ on most variables related to their teaching context.

Of the community and school context variables, a higher level of access to computers and more learning resources in the school showed relationships to TPACK confidence profile. The percent of low-income students, neighborhood, and state classification variables showed no relationship to TPACK. Of the classroom context variables, having more computers in the classroom related to higher levels of TPACK. Profiles did not differ significantly by grade level, subject taught, National Board certification area, or teaching courses targeting English language learners, special education, remedial, or regular education students. Outside of the school site, high-TPACK teachers reported more types of learning resources, higher numbers of learning supporters providing more support, more laptops, and a trend toward more use of the Internet for teaching ideas.

Because so many variables were being considered in these analyses, the concern may be raised that some of these findings represent a Type I error, finding a difference where none exists. The consistent finding that learning resources were significantly related to TPACK confidence suggests that those findings were not false positives. For the one variable that did not follow the consistent pattern that appeared across all the analyses, a Bonferroni correction was used. The finding that mid-TPACK teachers were more likely to report that they taught advanced students was significant even with a lower alpha level. More research is needed to explain what the relationship between TPACK confidence levels and teaching courses for advanced students might be. A discussion about how to understand the mid-TPACK profile is included in Chapter 8.

In the context of the differences in learning resources, the finding that computer access relates to TPACK confidence, while consistent with previous research, evokes new questions about the nature of the relationship between the technology and the development of confidence. A chicken-and-egg question of "which came first?" surrounds the discussion of technology in teaching; anecdotes abound of high-tech teachers providing computers with their own personal funds, suggesting that their interest, confidence, and knowledge preceded its application in their individual classrooms. On the other hand, studies have often shown the importance of exploration and experience in the development of interest in learning about computers (Busch, 1995; Chen, 1986), which would suggest that having the opportunity to gain experience is a prerequisite for knowledge development. Though this study is limited by the lack of information about whether respondents funded their current or past computer purchases, the finding that higher access at the school level relates to higher TPACK confidence suggests that even if some individuals do seek out more resources based on their own prior interest, decisions made at the school and district level to invest in computers could have a positive impact on the level of all teachers' TPACK confidence. It would be helpful to test this relationship through experimental or quasi-experimental studies.

Similarly, the relationship between learning resources and knowledge is correlational. It is possible that the existence of more learning support causes higher TPACK confidence, and that the lower numbers reported by low-TPACK teachers reflect an actual dearth of learning resources. It is also possible that high-TPACK teachers tend to be more aware of existing learning resources than their low-TPACK colleagues. The latter interpretation is supported by the observation that almost half of the 307 the respondents indicated that every *available* learning resource was also an *important* learning resource. Of the remaining 167, 103 marked at least one learning resources as important that they had previously marked unavailable. Relatively few respondents identified learning resources as available but not important to learning, raising the possibility that the respondents only marked them as available if they were also important. Both were significantly higher for the high-TPACK teachers than for their colleagues. This relationship could be further examined in a study in which the researchers knew the availability of resources for learning.

The relationship of TPACK confidence profile to learning supporters and the support they provide inside and especially outside of school raises several more questions. These analyses showed that total numbers matter; do certain supporters play key roles in supporting the learning of TPACK? What types of support are most important? Are there particular types of relationships that are uniquely important to high-, mid-, and low-TPACK teachers? A deeper look at these relationships will be the focus of the next chapter.

CHAPTER 7: WHO TAUGHT THE TEACHERS

In this chapter I address the question of how individuals in teachers' social networks and the support they provide relate to teachers' confidence in their technological pedagogical content knowledge, or TPACK (Mishra & Koehler, 2006). In Chapter 6, a relationship appeared between the number of individuals respondents named as learning supporters and their TPACK confidence level. A growing body of research is considering how the individuals in a teacher's social network provide access to important opportunities to learn. In this chapter I describe the respondents' networks of individuals who supported their learning, which I will refer to as their *learning networks*. I examine the relationship between respondents' rating of their TPACK and the various kinds of support accessed through those learning networks.

To this perspective of a learning network I add the idea of looking at how those individuals support learning across different settings. A useful framework is a *learning ecology*, which Barron defines as the "the accessed set of contexts, comprised of configurations of activities, material resources and relationships, found in co-located physical or virtual spaces that provide opportunities for learning" (Barron, 2004, p. 6). She found that students with higher levels of experience making and creating with technology had accessed more out-of-school and distributed resources. In the case of teachers learning to use technologies in teaching, this perspective suggests that interest, knowledge, and confidence may be gained through different "spaces" or settings, and brought to bear in the classroom. Prior research has shown that teachers who use computers more frequently at home have been found to report higher use in the classroom (Williams, Coles, Wilson, Richardson, & Tuson, 2000).

Support in work settings may also be important. Human infrastructure for tech support and administration is related to higher levels of technology use (Lawson & Coomber, 1999; Williams, Coles, Wilson, Richardson, & Tuson, 2000; Zhao, Pugh, Sheldon, & Byers, 2002). Colleagues have also been shown to play many different roles in supporting each others' successful technology implementation (Frank, Zhao, & Borman, 2004; Ryymin, Palonen, & Hakkarainen, 2008; Williams, Coles, Wilson, Richardson, & Tuson, 2000; Zhao, Pugh, Sheldon, & Byers, 2002). The current set of analyses explores which supporters in which settings provide which types of support to teachers, and whether these differ for respondents with different levels of TPACK confidence.

To explore how teachers' learning networks and the support they provide relate to TPACK, I turn to items in which respondents were asked to nominate their learning supporters. These items asked for both the types of support provided and the nature of the supporter's relationship with the respondent. The relationship data allowed me to examine both the distribution of the learning network across settings in the learning ecology, and the nature of the support accessed through those settings.

Organization of the Chapter

I examine the data from the point of view of the respondent in part 1 of this chapter. I explore the total number of supporters, the total amount of support across all supporters, and the number of types of support. I explore the amount of support in particular settings, and delve further into the availability of particular types of support, to examine how supporters and support provided each relate to TPACK confidence profile. These analyses show a relationship between higher TPACK and higher levels of three types of support that require more interaction with and initiative by the learner: learning together, connecting with others, and posing new challenges. I consider these to be *learning partner* roles.

In part 2, I focus the analysis on those learning partner roles. To examine where and from whom those types of support are accessed, I considered the supporter rather than the survey respondent as the unit of analysis. Learning supporters were categorized based on the nature and setting of their tie to the respondent: worksite, professional, personal, or unknown. These analyses allow me to explore the relationships between the nature of the ties and the kinds of support provided. Finally, I examine whether these relationships hold for teachers with different TPACK confidence profiles.

Each part begins with relevant measures, followed by analyses and summary. Discussion of overall findings concludes the chapter.

Part 1: Respondent-Centered Analyses

In this part I use a respondent-centered approach to examine how supporters and support provided each relate to TPACK confidence profile. These analyses consider support provided overall and specific types of support. In addition I examine supporters at the school site, in professional settings outside of the school, in personal settings, and in unknown settings.

Measures: Respondent-Centered

TPACK Confidence Profile

Respondents rated their technological pedagogical content knowledge (TPACK) on 5 items, which were averaged for each subject area taught. The highest TPACK self-rating across subjects for any respondent became the TPACK confidence score. Averaged scores (N = 307) ranged from 1 to 5, with a mean TPACK of 3.91 (SD = .80). For a full discussion of the TPACK measure, please see Chapter 5.

The continuous TPACK confidence variable was used to create to three profiles, representing high-, mid-, and low-TPACK teachers in this sample. High-TPACK teachers represented 31.3% of the sample, mid-TPACK teachers 28.3%, and 40.4% were identified as low-TPACK based on their TPACK confidence. For more about derivation of the three profiles, see Chapter 6.

Learning Supporters

Number. Survey participants were asked to list important people who support their learning to use technology for teaching. The item was presented as demonstrated in Figure 7-1. They were given up to 16 text fields in which they could list learning supporters by code name or initials. Four nominations to "self" were removed. The total number of people listed became the *number of learning supporters.* The total number of people listed became the *number of learning supporters.* The number of learning supporters ranged from 0 to 11, with a mean of 2.70 (SD = 1.88).

Please list important people (as many as you like) who **support your learning to use digital technologies with students**. Think about people inside and outside of school, teachers and non-teachers. You may use code names or initials -- we are not interested in their identities, but it will help us to ask you more information about how they help you learn. You do not have to fill in all the lines.

		How does this person support your learning? (Check all that apply.)								
	code name or intitials	Teaches me how to use technology	Lends me resources to help me learn (e.g., books)	Provides or helps secure funding for technology	Demonstrates technology use in lessons	Learns with me	Explains how tech can impact students	Pays me to learn to use technology (e.g., stipend, release time)	Poses challenges for me to find answers to	Connects me to other people to learn from
Person 1										
Person 2										
Person 3										

Figure 7-1. Survey item for nominating learning supporters. Respondents filled in the field with code names or initials for people who "support… learning to use digital technologies with students."

Setting. After nominating the supporters, respondents were asked to identify their relationship to the supporter from a list of 18 choices. Those learning supporters who were identified by their relationship to the respondent as not being in the school setting (e.g. home, district administrators, or product technology support) were tallied to create an *non-school supporters* variable. Analyses in Chapter 6 showed that high-TPACK teachers reported more non-school supporters than low-TPACK teachers. To further refine the analyses, non-school supporters were further split into *professional*, *personal*, and *unknown* supporters. The number of professional supporters (outside teacher colleagues, district IT, mentors, and administrators) supporting learning ranged from 0 to 6, with a mean of .46 (*SD* = .81) and a mode of 0. Personal supporters (family, friends, colleagues in another profession, and product technology support) supporting learning ranged from 0 to 4, with a mean of .43 (*SD* = .72) and a mode of 0. Unknown supporters (internet contacts, none of the above) supporting learning ranged from 0 to 2, with a mean of .11 (*SD* = .35) and a mode of 0.

Learning Support

Amount. Nine different ways in which learning supporters might support the learning of participants were listed. The types of support were based on prior work with adolescents, which examined the roles of parents in supporting interest development (Barron, Martin, Takeuchi, & Fithian, 2009), adjusted as appropriate for teachers, and refined through pilot testing. The support types are listed in table 7-1.

Table 7-1. Types of support available from at least one learning supporter, with frequency of that type of support among all respondents

Support	% of respondents
Teaches me how to use technology	82
Demonstrates technology use in lessons	60
Explains how tech can impact students	47
Learns with me	46
Connects me to other people to learn from	46
Provides or helps secure funding for technology	42
Lends me resources to help me learn (e.g. books)	41
Poses challenges for me to find answers to	26
Pays me to learn to use technology (e.g. stipend, release time)	20

For each learning supporter, participants indicated the nature of the support provided by each person by checking all the types that applied. The tally of all the kinds of support provided for each participant across all learning supporters became the *amount of support* score. Note that the same type of support may have been provided by multiple supporters, and was counted once for each time it was checked. Thus the respondent with the highest number of learning supporters (11) could in theory have had an amount of support score of 99. The tallies ranged from 0 to 55, with a mean amount of support of 7.31 (SD = 7.69).

Support available. In addition to the total amount of support, a *breadth* of types of support available variable tallied how many of the 9 different types of support were provided by at least one learning supporter for each respondent. The support breadth scores ranged from 0 to 9, with a mean breadth of support available of 4.10 (SD = 2.66) and a mode of 4.

Setting. The nature of the support each learning supporter provided was indicated through checkboxes. The 9 different types of support were based on research on the roles of parents in supporting their children's pursuit of technological fluency (Barron, Martin, Takeuchi, & Fithian, 2009), and modified to pertain to teachers in schools. The total amount of support that was provided by non-school supporters ranged from 0 to 33, with a mean of 2.78 (*SD* = 4.15) and a mode of 0. The total breadth of support that was provided by professional supporters ranged from 0 to 31, with a mean of 1.57 (*SD* = 3.39) and a mode of 0. Support from personal learning supporters ranged from 0 to 12, with a mean of .96 (*SD* = 1.85) and a mode of 0. Support provided by unknown supporters ranged from 0 to 8, with a mean of .25 (*SD* = .97) and a mode of 0.

Analyses: Respondent-Centered

In this section, analyses are presented that examine whether a series of continuous and dichotomous variables reflecting characteristics of the learning network were associated with TPACK confidence profiles. To facilitate interpretation of the results, each analysis was done individually; the issue of multiple comparisons will be addressed in the discussion.

Supporters

Overall number. To examine whether the number of supporters identified by participants differed by TPACK confidence level, a one-way ANOVA was run with TPACK confidence group as the between-subjects factor and total number of supporters as the dependent variable. There was a significant main effect of TPACK confidence group, F (2, 304) = 3.60, p = .03. Post-hoc analyses using Tukey's HSD showed that the high-TPACK teachers reported a higher average number of supporters (M = 3.11, SD = 2.29) than the mid-TPACK teachers (M = 2.48, SD = 1.65), a statistically significant difference. The difference between high- and low-TPACK teachers (M = 2.52, SD = 1.60) approached statistical significance (p = .06).

Worksite. To examine whether the number of supporters inside the school setting differed by TPACK confidence level, I ran a one-way ANOVA with TPACK confidence group as the factor and number of school supporters as the dependent variable. The main effect of TPACK confidence group was not statistically significant, F (2, 304) = 1.16, p = .32, indicating no meaningful difference between the different groups in number of supporters in the worksite setting. On average, high-TPACK teachers reported 1.86 learning supporters at school (*SD* = 1.60), mid-TPACK teachers 1.56 (*SD* = 1.38), and low-TPACK teachers 1.66 (*SD* = 1.19).

Offsite. To determine whether the number of non-school supporters nominated by respondents varied by TPACK confidence group, a one-way ANOVA was run with TPACK confidence profile as the factor and the number of non-school supporters as the dependent variable. Results indicated that there was a significant main effect of TPACK confidence group, F (2, 304) = 3.29, p = .04. Post-hoc analyses using Tukey's HSD showed that on average, high-TPACK teachers reported significantly more offsite supporters (M = 1.25, SD = 1.38), than low-TPACK teachers (M = .85, SD = 1.06). Mid-TPACK teachers reported an average of .92 (SD = 1.11) offsite learning supporters, which was not significantly different from the other two groups.

To further determine whether the differences in offsite learning supporters were driven by a particular setting, ANOVAs were run with TPACK confidence profile as the factor and number of non-school respondents as the dependent variable for each of the three subsets: professionals outside the worksite, personal settings, and unknown. Unknown setting supporters included "None of the above" (14 supporters reported by 13 respondents) and "Other Internet resource / online" (7 supporters reported by 7 respondents).

The results of the analyses showed the main effect of TPACK confidence group was significant for the number professional supporters, F (2, 304) = 2.99, p = .05, but not for supporters from personal settings, F (2, 304) = 1.83, p = .18, or unknown, F (2, 304) = .70, p = .50. Post-hoc analyses indicated that the significant differences in professional supporters appeared between the high- and low-TPACK groups; the average number of supporters for all groups and settings are shown in table 7-2.

Table 7-2. Number of learning supporters within settings, by TPACK confidence profile

	Supporters M (SD)				
	Low	Mid	High	*F*	*p*
Worksite	1.66 (1.19)	1.56 (1.38)	1.86 (1.60)	1.16	.32
Professional	.35 (.64)	.45 (.71)	.61 (1.05)	2.99	.05
Personal	.43 (.68)	.33 (.73)	.53 (.77)	1.83	.18
Unknown	.08 (.33)	.14 (.41)	.11 (.32)	.70	.50

Amount of Support

Overall. A one-way ANOVA examined the degree to which the amount of support provided by learning supporters varied by TPACK confidence group. Results indicated that there was a significant main effect of TPACK confidence profiles, $F\ (2, 304) = 5.76$, $p < .01$. Post-hoc analysis using Tukey's HSD indicated significant differences between the high-TPACK teachers and the other two groups; they reported a higher average amount of support ($M = 9.48$, $SD = 10.50$) than the mid-TPACK teachers ($M = 6.45$, $SD = 5.82$) and low-TPACK teachers ($M = 6.23$, $SD = 5.73$).

Overall available. A one-way ANOVA examined whether respondents in the three TPACK confidence groups differed in the number of types of support they had provided to them by at least one supporter. Results indicated that the main effect of profile was not statistically significant at the .05 level, $F\ (2, 304) = 2.55$, $p = .08$. Post-hoc analysis using Tukey's HSD indicated differences approaching significance between the high-TPACK teachers ($M = 4.54$, $SD = 3.02$) and low-TPACK teachers ($M = 3.73$, $SD = 2.44$); the mid-TPACK teachers were not significantly different from either of the other groups ($M = 4.15$, $SD = 2.47$).

Worksite. A one-way ANOVA examined the degree to which the amount of support provided by learning supporters in the school setting varied by TPACK confidence group. Results indicated that there were marginally significant main effect of profiles, $F\ (2, 304) = 2.98$, $p = .05$. Post-hoc analysis using Tukey's HSD indicated that the difference between high-TPACK teachers' worksite support and the other two groups' approached statistical significance. On average, high-TPACK teachers reported an average amount of support provided by supporters at school of 5.58 ($SD = 6.45$), with mid-TPACK teachers averaging 3.93 ($SD = 4.25$), and low-TPACK teachers 4.13 ($SD = 4.55$).

Offsite. A one-way ANOVA was run to determine whether the amount of support provided by offsite learning supporters varied by TPACK confidence group. Results indicated that there were significant main effect of profile, $F\ (2, 304) = 5.00$, $p < .01$. Post-hoc analyses showed that high-TPACK teachers reported significantly more offsite support ($M = 3.82$, $SD = 5.66$) than low-TPACK teachers ($M = 2.10$, *SD* = 2.89). The difference between high- and mid-TPACK teachers (*M* = 2.52, *SD* = 3.44) approached statistical significance ($p = .08$).

To further determine whether the differences offsite learning support were driven by supporters from a particular setting, ANOVAs were run for each of the three subsets: professional, personal, and unknown. The results of the analyses showed significant differences in the amount of professional support, $F(2, 304) = 4.83$, $p < .01$, but not in support from personal, $F(2, 304) = 1.68$, $p = .19$, or unknown settings, $F(2, 304) = 1.09$, $p = .34$. Post-hoc analyses indicated that the significant differences in professional support appeared between the high- and low-TPACK groups; the average amount of support for all groups and settings are shown in table 7-3.

Table 7-3. Amount of learning support within settings, by TPACK confidence profile

	Support M (SD)				
	Low	Mid	High	*F*	*p*
Worksite	4.13 (4.55)	3.93 (4.25)	5.58 (6.45)	2.98	.05
Professional	.98 (1.89)	1.52 (2.91)	2.39 (4.84)	4.83	<.01
Personal	.98 (1.85)	.68 (1.59)	1.18 (2.05)	1.68	.19
Unknown	.15 (.63)	.32 (1.16)	.26 (.89)	1.09	.34

Types of Support

Available. To determine the relationship of TPACK confidence to each of the types of support available to respondents, I ran a series of Chi-square analyses. Table 7-4 presents the percentage of teachers in each TPACK confidence profile that reported that each of the types of support was available to them from at least one learning supporter.

Teach technology use. The trend for all other types of support was reversed for teaching the learner to use technology. Low-TPACK teachers were most likely to report that they had at least one person teaching them to use technology for teaching, followed by mid-TPACK teachers, who were in turn more likely than high-TPACK teachers to report that someone taught them. The differences approached statistical significance.

Table 7-4. Support provided by at least one supporter, by TPACK confidence profile

	% with Support				
	Low	Mid	High	χ^2	*p*
Teaches technology	87.4	83.9	75.0	5.65	.06
Demonstrates in lessons	52.4	65.5	63.5	4.54	.10
Explains impact	46.8	47.1	46.9	.00	.99
Learns with me	40.3	43.7	54.2	4.36	.11
Connects with resources	43.5	40.2	53.1	3.41	.18
Provides funding	32.3	43.7	52.1	8.95	.01
Lends resources	36.3	43.7	44.8	1.97	.37
Poses challenges	20.2	26.4	33.3	4.88	.09
Pays for learning	14.5	20.7	27.1	5.32	.07

Demonstrate in lessons. Low-TPACK teachers were less likely to have a supporter who demonstrated technology use in the classroom; the difference approached statistical significance.

Explain impact of technology. There were no statistically significant differences by TPACK confidence profile in the number of respondents who had a supporter who explained how the use of technology impacts student learning.

Connect, collaborate, challenge. More of the high-TPACK teachers also reported that they had someone who connected them with other people to learn from, however the differences were not statistically significant. Having a supporter who learned with them and posed challenges for them to learn from trended upward with higher TPACK confidence profiles; these differences approached statistical significance.

Lend, purchase, pay. High-TPACK teachers were significantly more likely to report that they had someone funding their purchases of technology than their mid- or low-TPACK colleagues. The differences between profiles in having a supporter paying them to learn approached statistical significance, with higher TPACK confidence being associated with a higher likelihood of this type of support. There were no differences by TPACK confidence profile in the number of respondents who had a supporter who explained how the use of technology impacts student learning.

Amount. A series of one-way ANOVAs was run to determine whether the number of supporters providing each type of support varied by TPACK confidence group. Results are presented in figure 7-2. No significant differences appeared in the number of supporters who helped learners by teaching them to use technology, F (2, 304) = 1.71, p = .18, demonstrated use in lessons, F (2, 304) = 1.90, p = .15, or explained how technology impacts student learning, F (2, 304) = 1.88, p = .15. Statistically significant differences did appear by profile in the number of supporters who helped by connecting learners with resources, F (2, 304) = 6.32, $p < .01$, learning together, F (2, 304) = 6.85, $p < .01$, posing challenges, F (2, 304) = 8.76, $p < .01$, lending resources, F (2, 304) = 3.01, p = .05, funding equipment, F (2, 304) = 7.03, $p < .01$, and paying them to learn, F (2, 304) = 3.84, p = .02.

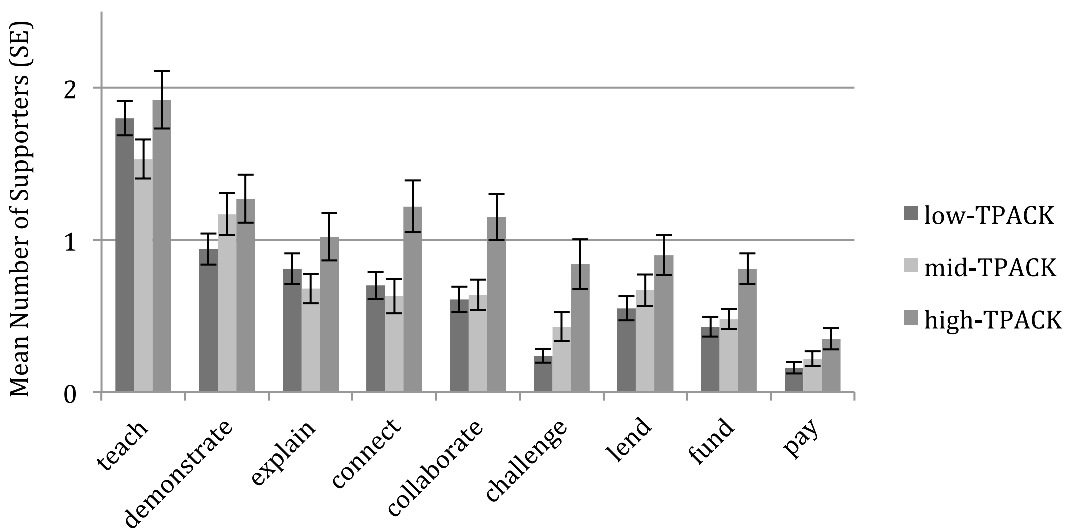

Figure 7-2. Mean number of supporters providing each type of support, by TPACK confidence profile. Types of support organized by Low-TPACK teachers' mean number of supporters. Error bars represent standard errors. High-TPACK teachers reported significantly more supporters providing all but the first three types of support.

Post-hoc analyses showed that high-TPACK teachers had significantly more supporters than both mid-TPACK and low-TPACK teachers who connect, collaborate, fund, and challenge them. Significant differences appeared between high- and low-TPACK teachers in lending and paying; mid-TPACK teachers were not significantly different from either group in these types of support.

Summary: Respondent-Centered

High-TPACK teachers reported the highest number of supporters and support provided on average than their colleagues, both overall and in offsite professional settings. Worksite supporters are most common for respondents at all levels of TPACK confidence; supporters from offsite professional and personal settings are less common. The relatively low numbers of offsite supporters may be explained by the nature of the question, which asked for "people who support your learning to use technology for teaching." However, discrepancies in the data suggest there may also be other issues at play. For example, in Chapter 6 we saw that technology-based professional development workshops were available to most respondents, yet respondents in all TPACK confidence profiles reported very low numbers of supporters who pay them to learn. This raises questions about whether teachers are being asked to learn on their own time, or whether the respondents neglected to list the higher-level administrators who are responsible for institutional support when answering this question, which specifically asked for them to identify individual people. Is setting up a workshop on a professional development day or paying for a sub not considered in this category? More research is needed to understand how sensitive the perception of having a learning supporter is to knowing the individual responsible for providing the institutional support.

Because so many variables were being considered in these analyses, the concern arises that some of these findings represent a Type I error: finding a difference where none exists. However, a consistent pattern of high-TPACK respondents having higher access to support across all the analyses helps to allay that concern.

These findings suggest that although a breadth of support types is associated with higher TPACK confidence levels, having more supporters providing specific kinds of support may also be conducive to higher TPACK confidence. The number of supporters teaching technology, demonstrating classroom use, and explaining how technology supports student learning were relatively high for the entire sample, and not significantly different for respondents with different TPACK confidence profiles.

High-TPACK teachers reported significantly more supporters who challenged them, collaborated with them, connected them to resources, funded equipment, lent resources, and paid them to learn. These six types of support fall into two groups: support that involves physical or monetary resources, and support that requires a higher level of interaction between supporter and learner. These last three support roles—connect, collaborate, and challenge—are the focus of the following analyses.

Who provides those kinds of support? Because of their more interactive nature, it becomes especially interesting to understand who is providing the support in these roles that can be described as learning partners. Do high-TPACK teachers have more learning partners at school than low- and mid-TPACK teachers, or do they find them in other settings outside the worksite? I seek to answer these questions in Part 2.

Part 2: Relationship-Centered Analyses of Learning Partner Roles

Of the 307 respondents in previous analyses, 279 nominated at least one supporter. Thirteen high-TPACK teachers nominated no learning supporters (13.5%); this was more than mid-TPACK (9.2%) or low-TPACK teachers (5.6%), however the difference was not statistically significant (χ^2 (2, N = 304) = 4.07, p = .13).

The 827 supporters nominated across the 279 respondents are the focus of the following analyses. Because analyses in the previous chapter suggested that TPACK confidence could interact with the perception of resource availability, the analyses will further explore whether the support provided by supporters differ by the TPACK confidence profile of the respondent who nominated them.

Measures: Learning Partner Roles

Relationships

Each supporter was identified having a relationship to the respondent best described as one of 18 choices listed in table 7-5. Nominations by respondents of "self" or "myself" were removed. Five supporters were not identified with a relationship, and are treating as missing for analyses involving setting.

Table 7-5. Relationships of supporters to respondents

	% of Supporters
Worksite	
School colleague: same subject area	22.3
School colleague: outside my subject area	13.7
School administrator	9.1
School technology mentor / coordinator	7.9
School technology support (IT)	10.0
Student	0.5
Parent	0.4
Professional	
Non-School Teacher Colleague: same subject area	2.6
Non-School Teacher Colleague: outside my subject area	2.6
District administrator	3.0
District technology mentor / coordinator	5.2
District technology support (IT)	4.0
Personal	
Spouse or significant other	5.6
Other family member	4.3
Friend	3.8
Non-School Colleague, other profession	1.7
Product technology support contact	0.9
Unknown	
Other Internet resource / online contact	0.9
None of the above	1.7

Based on the relationships, the supporters' locations were identified as worksite, professional, personal, or unknown. Worksite supporters (teachers, administrators, mentors and IT support at the same school) were the most common, comprising 63.9% of all supporters. Supporters outside of the school but in the education profession (district administrators, mentors, IT support, and teachers at other schools) made up 17.4% of supporters. Individuals in personal settings (spouse/significant other, family members, friends, colleagues in other professions, and product technology support) made up 16.2%, while those in an unknown setting (Internet contact, none of the above) were 2.6% of supporters.

Type of Support

Nine different ways in which learning supporters might support the learning of participants were listed in the survey item. For each learning supporter, participants indicated the nature of the support provided by each person by checking all the types that applied. The percentage of supporters that provided each kind of support is presented in table 7-6. The tally of all the kinds of support provided by each learning supporter is the *supporter breadth of support* score. Supporters' breadth of support ranged from 0 to a maximum of 9; the mean number of types of support was 2.71 (*SD* = 1.80), with a mode of 1.

Table 7-6. Percent of all supporters who provided each type of support for learning

Support	% of supporters
Teaches me how to use technology	65.2
Demonstrates technology use in lessons	41.0
Explains how tech can impact students	31.0
Connects me to other people to learn from	31.2
Learns with me	29.3
Poses challenges for me to find answers to	17.8
Lends me resources to help me learn (e.g. books)	25.6
Provides or helps secure funding for technology	20.8
Pays me to learn to use technology (e.g. stipend, release time)	8.7

Analyses: Learning Partner Roles

Setting

Breadth of support. A one-way ANOVA was run to determine whether the breadth of support provided differed by the supporter's setting. Results indicated that there were significant differences by setting, F (3, 818) = 11.84, $p < .01$. Post-hoc analyses showed that supporters in the professional settings provided more different kinds of support ($M = 3.43$, $SD = 1.96$) than worksite supporters ($M = 2.65$, $SD = 1.78$) and supporters in personal settings ($M = 2.21$, $SD = 1.54$); unknown supporters were not significantly different from any other setting.

Types of support. Chi-square analyses were run to determine whether three types of support—brokering resources, collaborating in learning, and posing challenges—were more strongly associated with learning partners in particular settings. Table 7-7 presents the results.

Table 7-7. Proportion of supporters providing support by setting

Support	Worksite	Professional	Personal	Unknown	χ^2	p
Connects me	27.4	48.3	26.3	47.6	26.86	<.01
Learns with me	34.9	15.4	27.1	4.8	27.53	<.01
Challenges me	15.4	25.2	19.5	19.0	7.60	.06

The three types of learning support showed different patterns across settings. Connections to other people to learn from were significantly more likely to come from either professional supporters or supporters in unknown settings, than in worksite or personal settings. Learning supporters in the school were significantly more likely to learn with the respondent than supporters in professional, personal, or unknown settings. More professional supporters were reported to pose challenges than supporters in the other settings, a difference that approached statistical significance.

Differences between TPACK Confidence Profiles

Having established that the three different types of learning partner support were differentially distributed across settings, the question remained whether those distributions differ by TPACK confidence profile. A Chi-square analysis for each type of support examined the proportion of supporters within each setting who provided learning partner support to respondents in each TPACK confidence profile. Table 7-8 presents these results.

Connections to others. The number of supporters providing connections to others was highest for high-TPACK teachers in every setting. The difference was statistically significant at the worksite. Mid-TPACK teachers tended to report levels similar to low-TPACK teachers.

Learning together. The number of supporters at the worksite who were reported to learn together with the respondent increased with increasing TPACK confidence levels. In addition, high-TPACK teachers reported higher numbers of professional learning partners; however, mid-TPACK teachers less likely than low-TPACK to learn with professional supporters. Learning together with supporters in personal and unknown settings was not significantly different for different TPACK confidence profiles.

Table 7-8. Distribution of support by setting of supporter and TPACK confidence level of respondent

	N	Low TPACK	Mid TPACK	High TPACK	χ^2	*p*
Connects me						
Worksite	525	25.4	21.2	34.6	7.82	<.05
Professional	143	43.2	40.0	57.6	3.62	.16
Personal	133	24.5	24.1	29.4	.41	.81
Unknown	21	40.0	50.0	50.0	.15	.92
Collaborates with me						
Worksite	525	27.3	34.3	44.1	12.10	<.01
Professional	143	13.6	2.5	25.4	9.77	<.01
Personal	133	26.4	27.6	27.5	.02	.99
Unknown	21	0.0	0.0	10.0	.16	.56
Challenges me						
Worksite	525	8.1	16.1	23.5	17.42	<.01
Professional	143	6.8	22.5	40.7	15.55	<.01
Personal	133	18.9	17.2	21.6	.25	.88
Unknown	21	0.0	16.7	30.0	1.98	.37

Posing challenges. The proportion of supporters who were reported to pose learning challenges increased with increasing TPACK confidence levels in three of four settings. The differences were significant in the worksite and professional settings. A similar trend appeared from supporters in an unknown setting, however the sample size was too small to show statistical significance. Only personal supporters did not show the strong pattern of increasing levels of challenge by TPACK confidence level.

Summary: Learning Partner Roles

This set of analyses sought to describe the distribution of partners who provided three highly interactive types of learning support across settings in the teacher's learning ecology. In addition to understanding whether certain types of learning support were associated with learning partners in certain settings, differences were explored between supporters of teachers with different TPACK confidence levels.

Findings showed that learning partners were differentially likely to provide support across settings, depending on the type of support. While learning together was most likely in the worksite setting, connecting with others was most likely among professional supporters and among supporters in unknown settings. Posing challenges was common among professional supporters.

The access to these three types of support was different for supporters of teachers at different levels of TPACK however. While the professional supporters tended to be equally likely to connect, collaborate, or challenge regardless of TPACK confidence level, supporters in other settings were more likely to provide these forms of support if nominated by a teacher with higher TPACK. There were exceptions to the trend however, as for example personal supporters of mid-TPACK teachers were less likely to learn together with them than expected. More research is needed to understand what might be different about the mid-TPACK teachers.

An important insight from these analyses is that high-TPACK teachers get more support both inside and outside of the school setting for all three highly interactive types of learning support. Metaphorically, this represents a rising tide of learning partner support across all settings, rather than an overflow from one to another. Low-TPACK teachers however, with relatively little support from learning partners inside educational settings, get higher proportions of their overall support from partners in personal settings.

Chapter 7 Summary and Discussion

The focus of this chapter was on the people who support teachers' learning to use technology for teaching. Through respondent-centered analyses, I examined the relationship between the number and setting of their supporters to teachers' TPACK confidence profile. Higher-TPACK teachers tended to have more supporters overall, and those higher numbers were driven by both worksite supporters and higher levels of professional supporters outside the school. The implication of these findings is that individuals in professional settings outside the worksite may play a potentially valuable part in helping teachers learn to use technology for teaching.

Amount of Support

The higher number of supporters was reflected in higher amounts of support provided. A broader range of support roles was filled for high-TPACK teachers, but the difference was not statistically significant. However when the total amount of support of all types across all supporters was analyzed the high-TPACK teachers reported significantly more than either of the other two groups. It is tempting to interpret this as that more providers of more support are beneficial to TPACK development. This would align with the theory of social capital, which suggests that resources embedded in, or accessed through, members in their social network give individuals the capacity to develop human capital (Lin, 2001; 2004). In the context of teachers' TPACK, the idea is that through their social networks, teachers gain access to social capital such as information, computers, or challenges, from which they build their own human capital, or knowledge. We would expect that teachers with more people to learn from, or learning supporters who provide more support for learning to teach with technology, would be likely to learn more about how to use technology with students.

This study is correlational however, and the reverse relationship is also possible: high-TPACK teachers may be more aware of both the individuals providing support, and the ways in which the support provided helps them learn. For example, a high-TPACK teacher may be more conscious of an individual who made the decision to fund a technology workshop, or identify the person who provided equipment as a supporter of their learning. Or there may be another, unseen factor impacting both resources and TPACK confidence for teachers, such as a culture of professionalism at the school site or a more general focus on teacher learning. More research on the nature of the relationship between teachers' TPACK confidence level and the perception of support would be valuable to illuminate the interaction between confidence and learning networks.

Types of Support

When looking at particular types of support, an interesting pattern emerged. Most frequent were the three types that had to do with the provision of knowledge by the supporter: teaches me technology, demonstrates use in lessons, and explains how technology impacts student learning. Three other types of support also involved provision by the supporter, this time of physical or monetary resources: lends me resources (e.g., books), helps secure funding for equipment, and pays me to learn.

These were uncommon; the higher the level of expenditure, the less common the support. In the middle were three types of support that involved more initiative on the part of the learner and a higher level of interaction between learner and supporter: connects me with others to learn from, learns with me, and poses challenges for me to learn. All three of these involve an awareness of the learning needs of the teacher. All of these were significantly more common among supporters of high-TPACK teachers.

Research in in-service teacher learning has increasingly recommended that quality professional development is collaborative, contextualized, and long-term (Darling-Hammond & Richardson, 2009). These findings suggest that high-TPACK teachers have more collaborative and potentially longer-term learning experiences, but the question became the extent to which the context played a role in the support relationship. The nomination of learning supporters was prompted to address specifically those people who helped respondents learn to use technology for teaching. Although two-thirds of supporters were from the respondent's school, one in six supporters named was family members, friends, product technology support, or other professionals not in education. The analyses of setting showed that a higher TPACK confidence level was associated with more worksite and professional partners for all three types of support. Learning supporters in personal settings provided similar levels of interactive support to teachers with all TPACK confidence profiles. However, because lower-TPACK teachers had fewer of their learning supporters providing connections to others, collaboration, and challenge than their higher-TPACK colleagues, the support of people in personal settings accounted for a higher proportion of the relatively little partner support they had.

Many policy makers and administrators are eager to target interventions to raise teachers' levels of technological pedagogical content knowledge. Although this study is correlational and care should be taken in making predictions, several potential targets for intervention are suggested by these findings. The theoretical basis for technological pedagogical content knowledge as well as these findings both support interventions that connect teachers with learning partners inside their worksite and profession. In line with research on teacher professional development in general, the relationship between more interactive types of support and higher TPACK suggest that collaborative, long-term learning relationships are important. Above all, thinking of teacher learning support as an ongoing partnership, rather than delivery or knowledge or resources, may be key to helping teachers learn to use new technologies with their students.

Chapter 8: Discussion

The confluence of more funding for technology in schools, lower prices of hardware and software, and better design of technology user interfaces has led to a much greater potential for not only early-adopters, but all teachers, to use new technologies in their teaching. However there is a concern that technology is not being used to its full potential to support students' learning; a key factor is the extent to which teachers know how to use technologies in ways that support students' conceptual understanding. Teachers' confidence in their knowledge of how to use technology to support student learning, known as technological pedagogical content knowledge or TPACK (Mishra & Koehler, 2006), was the focus of this dissertation. In it I explored the relationship of TPACK confidence to the classroom contexts of teachers and the learning resources available inside and outside the work site. Analyses of the social learning networks of teachers—the individuals who supported their learning to use technology for teaching—provided valuable insights into the learning ecologies associated with higher TPACK confidence.

Review of the Study

This study was designed to give insights into how confidence in technological pedagogical content knowledge (TPACK) related to students' use of technology in school, and how it related to the teaching and learning contexts of accomplished teachers. It explored resource availability across settings in the teacher's learning ecology, with a special focus on the people in respondents' learning networks who provided access to key types of support. I explored multiple links in the chain leading from teacher education to student learning: from the teacher's learning resources to confidence in their knowledge of how to use technology for teaching, and from that confidence to student use of computers. This was a descriptive study, and as such the aim was to map the landscape and discover areas of high potential for future research and intervention.

This dissertation drew from an unusual data set, which featured teachers with high pedagogical content knowledge (PCK). Much of the research done on teachers' capacity to use technologies to teach has been in one of three categories: studies of relatively large groups of pre-service and novice teachers (e.g., Angeli 2005; Darling-Hammond, Chung, & Frelow, 2002; Schmidt, et al., 2009), smaller groups and case studies of teachers with varying levels of experience (e.g., Hennessy, Ruthven, & Brindley, 2002; Hughes, 2005; Meskill, Mossop, DiAngelo, & Pasquale, 2005; Mishra & Koehler, 2006; Niess, 2005; Snoeyink & Ertmer, 2001/2), and studies that examine large numbers of teachers with a range of experience. These last typically use years of experience as an indicator of expertise (Becker, 2000; Knezek & Christiansen, 2009; Russell, Bebell, O'Dwyer, & O'Connor, 2003; Williams, Coles, Wilson, Richardson, & Tuson, 2000), or occasionally self-report (Archambault & Crippen, 2009). This study contributes insights from a large sample of accomplished teachers, as indicated by certification by the National Board for Professional Teaching Standards.

The decision to solicit participation from National Board Certified Teachers (NBCTs) was driven by the combination of a need to provide insights into expert teachers' practices and contexts, and a desire to focus on the variability in the "technological" part of technological pedagogical content knowledge. Although there is no perfect way to find a large group of teachers with high levels of pedagogical content knowledge (PCK), National Board Certification serves as an indicator that the teacher has performed adequately when evaluated against stringent professional standards. The fact that that these individuals are certified by the National Board for Professional Teaching Standards addresses the potential concern that low TPACK scores reflects low pedagogical content knowledge (PCK), rather than variability in knowledge about new technologies' applications in teaching. It also allows for analyses that examine years of service without the assumption that they represent expertise.

The large sample of 307 teachers from across subject areas and grade levels, and with a wide range of experience—from 6 to 46 years—presents opportunities to explore patterns and to make more careful distinctions across and within groups of teachers. It is the benefit of this type of survey data to be able to detect relatively small but meaningful differences that might escape detection in studies with a small sample size. For the study of technology use in teaching, this approach allows us to compare elementary and secondary teachers, teachers with different levels of computer access, teachers of different ages and years of experience, and teachers with different levels of confidence in their TPACK.

The measures used to explore the terrain are a key part of this mapping exercise. The central measure was a series of items in which respondents rated their TPACK confidence. For the online survey I modified a set of questions designed for preservice elementary teachers to self-assess their TPACK (Schmidt, et al., 2009). The items had been validated through expert review and shown to be internally consistent. I made slight word changes to reflect the experiences of in-service teachers and presented a set of items for each subject taught. Equally important were other measures: frequency and breadth of teacher computer use with students; measures of technology use in the teachers' personal lives; items relating to the school, classroom, and personal resources available for learning; and lists of learning supporters that gave valuable insights into social interactions across settings. Taken together these measures provided rich opportunities to discover relationships and suggest avenues for supporting teacher learning of new technologies.

Selected Results

This study contributed to the theoretical understanding of TPACK by exploring the relationship of TPACK confidence to confidence in technology more generally, which was possible due to the high pedagogical content knowledge (PCK) of the participants. This study also explored the relationships of TPACK confidence with student computer use in class, the teaching contexts of participants, and the learning resources of teachers. Although the study was descriptive in nature and the results correlational, the results suggest productive directions for future interventions and design studies. The analyses provided answers to several research questions, addressed in chapters 5, 6, and 7. In this section I highlight a few of the main findings.

TPACK Confidence Is Not Just Being "Tech Savvy"

Overall, the results provided evidence that TPACK confidence is different from, though related to, confidence in knowledge of technology (TK). Conceptually it is easy to distinguish between the idea of knowing how to use a particular technology, and understanding how to use it in the classroom to teach a particular student a specific topic. The data provided evidence that this difference is real for teachers as well: the distribution of TK confidence was normally distributed across the entire response scale from 1 (strongly disagree) to 5 (strongly agree), while the TPACK confidence distribution had a long tail to the left and a median and mode at 4 (agree). Correlations showed that a measure of technology skills through familiarity with Internet terms (Hargittai, 2005) shared over three times as much variability with TK confidence as with TPACK confidence (50% and 16% respectively), suggesting that TPACK confidence is far less associated with general computer proficiency. The difference in ranges raises questions about what teachers consider adequate technology knowledge for teaching. Is technology knowledge less relevant in teaching contexts, is the field of relevant technologies more constrained, is the standard for "knowing" lower? Are teachers comparing themselves to different groups of people when rating their TPACK confidence and their TK confidence? Is confidence in knowledge an accurate representation of what teachers can do with new technologies? Future research is needed to explore what it means to rate technology knowledge low while rating TPACK high.

It is less clear that the measures captured the theoretical distinctions between TPACK confidence and confidence in technological pedagogical knowledge (TPK), pedagogical content knowledge (PCK), and technological content knowledge (TCK). The TPACK and TPK confidence scores shared over 50% of their variability, and the two single items designed to measure TCK and PCK loaded on the same dimension as TPACK items in an exploratory factor analysis. Taken together, these analyses support the theoretical distinction between confidence in knowledge of technology (TK), and in knowledge of how to use technology to support student learning (TPACK), but they raise questions about the survey design, and about whether teachers perceive TPACK as distinct from the TPK, TCK, and PCK constructs.

TPACK Confidence Is Associated With Student Technology Use in Class

Respondents' confidence in their TPACK showed associations with two different measures of student technology use in class. The goal of research in both educational technology and teacher professional development is ultimately to provide better learning opportunities for students, and these findings provide links in the middle of a chain of evidence between teacher knowledge of how to use technology for teaching and student learning outcomes. That chain is still fragile however. Teachers who reported higher TPACK scores tended to report that they assigned computer activities to students in class more frequently, but when the analyses were run separately for teachers with high and low numbers of computers in the classroom, the relationship became statistically insignificant. A stronger association appeared between teachers' TPACK confidence and range of production activities they had ever assigned to students. This breadth of exploration score, measured over a longer time frame and less tied to available computers, showed a robust relationship to TPACK confidence.

This relationship between TPACK confidence and production activities bears closer examination, as it helps illuminate what the TPACK confidence items measure. High-TPACK teachers were more likely to have assigned a broader range of production activities to students. The production activities all involved some form of product to be shared with others, which can be seen as contributing to students' skills for participation in society (Jenkins, Clinton, Purushotma, Robinson, & Weigel, 2006), or as elements of 21st century or digital-age learning (CEO Forum, 2002; ISTE, 2007; Partnership for 21st Century Skills, n.d.). These activities can be used to support learning of key subject area concepts and procedures, as suggested by the activity structures developed by Harris and colleagues (Harris, Mishra, & Koehler, 2009). Further research into the relationship between TPACK confidence and exploration of production activities may be guided by theories such as self-efficacy (Bandura, 1997), which focuses attention on persistence in the face of obstacles, or adaptive expertise (Hatano & Inagaki, 1986), which considers adaptability to new contexts and application of expert judgment.

TPACK Confidence Not Associated with Age or School Characteristics

Findings showed no relationship between TPACK confidence and the teaching context of respondents. Almost no TPACK-related differences appeared in descriptions of school communities, subjects, target populations, and grade levels. The only statistically significant relationship was between the mid-TPACK profile and teaching courses for advanced students, a finding that requires further investigation. In a data set made up of accomplished teachers, respondents' ages and years teaching were unrelated to TPACK confidence. Low, common levels of computer access in the school failed to differentiate between respondents with different TPACK confidence levels; only higher levels of access showed a relationship. At the individual, classroom, and school level, these inalterable factors were unrelated to teachers' confidence in their TPACK.

TPACK Confidence Is Associated with Teachers' Social Learning Networks

Instead there was a consistent and meaningful difference among low-, mid-, and high-TPACK teachers in the availability of resources to support teachers' learning about technology. This finding spanned physical, online, and social resources. Of special interest was the finding that teachers with higher TPACK confidence named more individuals who supported their learning to use new technologies for teaching. Not only was a larger learning network associated with higher TPACK confidence, but the types of support they provided as well. Supporters of high-TPACK teachers were significantly more likely to connect the respondents who nominated them with other people to learn from, learn together with them, and pose challenges for them to learn something new. These three types of support—connecting, collaborating, and challenging—have in common that they involve a more personal understanding of the teachers' learning needs and developmental trajectory than the most common kinds of support: teaching technology applications, demonstrating in class, and explaining the impact of technology on students.

These findings are correlational, which means that the causal relationship between TPACK and learning resources may go either way, or both may be caused by another factor. This begs the question what the relationship is between TPACK confidence and learning resources? Although at first glance the obvious assumption is that having resources allows for development of confidence in knowledge, the alternate direction is interesting to consider: does having confidence and/or knowledge lead to a heightened awareness of the existence of resources? Do teachers with higher TPACK notice or value the existing resources to a greater extent than their lower-TPACK colleagues? Do they seek out more opportunities to learn? Do they tend to develop more personal relationships with key learning supporters, leading to higher numbers of supporters providing more types of support? Does the relationship go both ways at once, as for example having more computers in the classroom allows teachers to develop a better understanding of how they can be used to support instruction, while at the same time teachers who understand computers' use in teaching advocate more strongly for more of them in their classrooms? Or is there another latent variable such as the culture of the school or district, which leads teachers to both bolster their confidence and become aware of the resources available for them to grow? These questions offer many important avenues for further study.

Implications

This dissertation has both theoretical and practical implications. Theoretically, this dissertation lends support to the idea that scholars can "add on" to the PCK conceptual framework. By surveying accomplished teachers I was able to look for variability in one aspect of the knowledge base of teachers, namely technology use. The use of appropriate tools to support instruction may be seen as embedded in pedagogical content knowledge, but in the case of new technologies this part of the knowledge base changes at a high rate. In TPACK, one of the many parts of PCK has been extracted and insights gained through a three-part framework. This may be useful in other areas of research related to pedagogical content knowledge, such as literacy or assessment.

These findings also contribute to the ongoing exploration of the boundaries of the TPACK conceptual framework. While supporting the distinction between technological knowledge (TK) and the knowledge of how to use technology to support student learning (TPACK), the exploratory factor analysis, correlations, and distributions also raise questions about whether teachers make a distinction between TPACK, PCK, TPK, and TCK in their practice.

For research, this dissertation provides insights into the correlates of the TPACK confidence score. There were no statistically significant differences in TPACK confidence among teachers of different grade levels, subject areas, and student populations. Yet it related to student experiences and specifically to their access to a breadth of activities related to 21st century skills. It related to resources and social networks in teachers' learning ecologies. From all these perspectives, the TPACK confidence measure captured important distinctions that we care about.

For those who design learning experiences for teachers, this dissertation contributes to the literature about how teachers learn, and specifically how they learn to use new technologies to support student learning, by exploring the concept of a knowledge base that spans settings in the teachers' life. The high rate at which technology develops makes this an interesting case for the study of teacher learning, and insights gained in the area of TPACK may be useful for developing other areas in a teacher's knowledge base by considering the roles of learning supporters inside and outside the worksite.

Recognizing that scholars in the field of teacher professional development have long been advocating for more collaborative, long-term learning experiences, these findings reinforce the idea that those may be particularly valuable for technology integration, as they provide a different learning experience than the more common direct instruction. This dissertation adds another perspective by adding on the learning ecologies framework, showing the ways in which learning partners outside of the worksite setting might provide important forms of collaborative support.

Design Opportunities

If we believe that it is important for teachers to develop technological pedagogical content knowledge (TPACK), it may be necessary to change current practices in teacher learning of new technologies. Though the study is descriptive and not prescriptive, findings point to a number of potential leverage points for the design of learning opportunities for teachers.

Focus on TPACK and Exploration

Because TPACK is technology knowledge in the context of student learning, which is different from technology knowledge (TK), it is important to make sure teachers are given opportunities to learn about the technologies in a way that relates to concepts in the curriculum in their subject area and grade level. Teachers of all subjects, levels, and school contexts have the potential to develop TPACK confidence. Recognizing that confidence in TPACK is associated with exploring new activities, learning experiences should allow teachers learn about a wide variety of tools available, so that they may develop their judgment about the ones best suited for their learning objectives for their students. Willingness to change is important to continued growth as a professional, but professional judgment will dictate that not all technologies are suitable or work in ways that serve lesson objectives. Teachers need opportunities to develop TPACK through trying out new activities and determining which tools best support student learning outcomes.

Flexible Learning Environments

Teachers often have very constrained schedules, and need flexibility of time and place for learning. High-TPACK teachers were significantly more likely to report that they had a teacher laptop. Providing teachers with mobile computing devices helps them access experts and learning resources in a range of locations and at times that suit them. From the teacher next door to a family member or a colleague halfway around the globe, anywhere, anytime access is important. High-TPACK teachers also reported a broader range of resources available to help them learn to use technology for teaching. Teachers as learners have different strengths and preferred learning styles, so it is important to provide an array of learning resources. Printed text, online video, face-to-face demonstrations are all valuable, and having more increases the likelihood for learning.

Learning Partnerships

Results indicate it could be valuable for teachers to work with supporters who connect them with the right resource at the right time, learn together with them about a topic of mutual interest, or pose challenges suitable to the their interest and knowledge level. These types of learning partnerships are at least in part teacher-initiated, and include awareness of the individual teacher's current context and goals. The focus on settings in these analyses suggests that this type of partnership should be supported within settings related to the teaching profession.

Open Questions about the Role of Computers in Developing TPACK Confidence

When designing the study, I was conscious that both developing knowledge and applying it might be heavily dependent on access to computers. I included several items relating to the presence of computers at home and in the classroom in the survey, but as analyses progressed, several questions arose that were difficult to answer.

Funding

Because this survey gathered information about TPACK confidence, past activities, and access concurrently, we cannot make causal inferences about their relationships. A question that is not answerable from this data is whether the teachers bought their own laptops and classroom computers. If not, who funded them, and how much effort was required by the teacher to get them? These questions speak to the prior inclination of the teacher to engage with and advocate for technology. Do higher numbers of computers mean that the teacher was more interested in technology, a stronger advocate, more technologically adept, or had higher TPACK before having computers available? Or did having higher levels of access in the worksite setting provide opportunities to develop knowledge through exploration? It could be both, or neither. The relationship between higher TPACK confidence and increased resources at the school level suggest the possibility of administrator buy-in playing a role in TPACK development. It would be interesting to do further analyses of learning supporters in school and district administrative roles and how their support might interact with TPACK.

Levels of Access

The distinction between computers available on demand in the classroom and those available on a part-time basis or through additional effort has been made before in studies (e.g., Becker, 2000) and rings true to teachers who lose valuable minutes walking their students to a computer lab. When I piloted the measures, respondents seemed to understand the distinction between "in the classroom or where you teach" and "available for check-out or reservation." But with the much larger sample, confusion was discovered. Is a mobile cart that is available for checkout also in the classroom? Does the school count as "where you teach"? This confusion appeared when responses for classroom and checkout numbers matched exactly, or respondents reported over 100 computers in the classroom. However, I had asked for mobile and desktop computers separately; I went back and recoded all responses that had potential for duplicates in the numbers to the lowest defensible number. This adjustment has implications for the findings, as I may have missed an effect that was there (a Type II error) stronger than the relationship in these analyses. I was also unable to use the continuous variable to examine what level of computer access is related to higher TPACK. Since Becker showed an effect for five or more computers in the classroom, this number has become a standard. However that survey item was ordinal, not continuous. Are five computers that much better than four? How much better might it be to have ten? How much more effective is a one-to-one classroom environment? As a result of the issues with the items in this survey, I could not treat these as continuous variables, which would have allowed for more in-depth and informative analyses.

Quantity and quality are related because quality impacts what is counted. As one respondent pointed out, 10-year-old computers don't do what newer computers do. In this analysis, I may have over-estimated the number of computers that could be used with relevant content software and production activities. On the other hand, handheld computers can be used to support a wide array of content learning, and since the survey, powerful tablet computers have arrived. To the extent that teachers and their students had access to such devices, I may have under-estimated levels of access in the school or classroom. Future studies will undoubtedly explore what types of devices are good enough to support effective student learning experiences.

For every question answered about computer access, several more arose. Clearly access to computers is relevant to TPACK confidence; but the nature of the relationship is still a rich area for future research. Furthermore it is research much needed by those making decisions about how to spend scarce funds in schools. In this context the findings relating to computer access should tested with further empirical studies.

Limitations

There are a number of limitations associated with the study described in this dissertation that restrict the claims that can be made and suggest future directions for research.

Sample

Any study relying on survey data is subject to potential limits to generalizability due to low response rate, response bias, and poor representativeness of the sample on several characteristics considered salient to the findings. The current study had a low response rate, perhaps due to the length of the survey, its topic, or its online format. Analyses suggest that on several dimensions of interest the sample is representative of the larger universe of teachers in the United States. Respondents were comparable to respondents of other published studies in their distribution on several measures of technology use and attitudes, but used the Internet more for teaching ideas. There were fewer male and/or minority teachers relative to the larger teaching population. Because these variables may relate to different patterns of technology access and use, or differences in learning support and resources, extending these findings beyond the sample should be done with caution.

The sample was chosen explicitly to reflect teachers with high pedagogical content knowledge. National Board Certification is one indicator, but not every accomplished teacher is National Board Certified. Further research is needed to determine the extent to which these findings relate to other groups of teachers.

Definitions

A number of issues arose with the definitions of variables in this study. As discussed above, what constitutes a useful computer was left open to the respondent, and the calculation of the number of computers in the school and classroom became challenging due to the flexible implementation of mobile computers. Similarly, the production activities used in the activity exploration scores were framed very broadly (e.g., “Use a simulation to model a real life situation or set of data”), which leads to the possibility that one respondent interpreted a particular tool such as Geometer Sketchpad as a simulation while another did not. These more general definitions and high-level categorizations limit the application of findings to particular tools or tool genres.

Activities such as reading comprehension quizzes, fitness charts, Internet research or word processing were not included in the production activities list, but were rather combined into an aggregate measure of frequency. These are valuable and pedagogically important activities and can be seen as productive in a sense, although the products are seldom shared with anyone other than the teacher. The question becomes how these types of activities relate to TPACK and whether they might require a different knowledge than those listed in the production activity list.

A great deal of work has been done in the area of assessing pedagogical content knowledge (PCK). Assessment is made difficult by the need to focus on a particular concept at a specific level (e.g., understanding place values). This difficulty is amplified when adding another dimension such as technology. For example, teaching science involves a great many subjects and concepts, and is very different in primary grades as compared to at the high school level. There are also a great many technologies that may be used to support learning of science topics and concepts. The nature of this study made it prohibitive to focus on a particular content area and level. More studies are needed to look at the particular interactions between tool and content; this work has been started but there is much still to be done (e.g., AACTE, 2008; Krauskopf, Zahn, & Hesse, 2011).

Self-Report

All reports are the perception of the respondents. This data set provides no way to triangulate the responses of participants with objective data, such as for example the socio-economic status of the students. Because the actual school at which participants teach is not known, the possibility exists that respondents under- or over-estimated the income levels of the students at their schools. All findings should be interpreted as relating to teachers' perceptions, which means that generalizing to other teachers based on the actual demographics may be misleading.

Self-Rating

In this survey, all knowledge measures are self-rated. I chose to call the scores "TPACK confidence" in recognition that there was no objective measure of what the respondents actually knew about using technologies to support student learning. As discussed above, these scores may be interpreted as reflecting self-efficacy expectations, flexibility, or change-orientation measures.

Closer examination of the distribution of the TPACK confidence scores revealed that close to one-third of participants' responses averaged 4.0, corresponding to "agree." To preserve the meaning of the scores and to keep groups roughly even, these respondents were treated as a separate group from those averaging less (low-TPACK) or more (high-TPACK). In several analyses, the mid-TPACK group did not follow the trend in proportions predicted with rising TPACK confidence. This leads me to question whether the mid-TPACK group was in fact a mix of 1) respondents at the high end of the low-TPACK range and 2) respondents at the low end of the high-TPACK range.

Incomplete Learning Networks

The learning partner findings are based on an egocentric nomination study. As such, no information is available about the relationships of the key players to each other, and how those relationships may influence the support provided to the respondent. Further, the item asked for "important" learning supporters only; social network studies have often pointed out the potential for important resources to be accessed through "weak ties" in schools (Penuel, Riel, Krause, & Frank, 2009; Ryymin, Palonen, & Hakkarainen, 2008). It may be that an individual in the teacher's social learning network is providing key types of support, even though the teacher doesn't think of that person as being an important person who supports their learning. Furthermore there may be ways in which the relationships between learning supporters – administrators at the school and district, for example – impact the learning experience of the teacher.

Multiple Comparisons

Because so many variables were being considered in these analyses, it is possible that some of these findings represent a Type I error, finding a difference where none exists. The finding that teachers of advanced students were more likely to rate themselves as high-TPACK may represent such a false discovery, and more research is needed to confirm this finding. However, the consistent pattern that high-TPACK respondents had more access to support across all the analyses helps to allay the concern that relationships achieved statistical significance by chance.

Future Directions

Although it answers many questions, this dissertation raises still more. There are ample directions for future research suggested by these analyses, through continued work with the current data, analyses of supplemental data collected in the same survey, and new studies employing other methodologies that complement this data set.

One direction for future studies is to analyze this data set from different perspectives. For example, it would be interesting to focus on respondents who have no learning partners, or many. By examining the extreme cases, we might gain a better understanding of the variability of experiences between teachers in different types of social networks. Similarly, questions were raised by these findings about the ways in which learning supporters with different job functions provide different kinds of support. Do administrators and colleagues appear to play different roles in the development of TPACK confidence? Does the focus on settings in the learning ecology framework provide enough insights, or do we need to expand the ecological metaphor to include the nature of other organisms in those settings? This data set cannot provide causal connections, but may provide insights into relationships worthy of future study.

Another direction to take the current data is to explore more deeply dimensions related to the TPACK framework, namely subject area and grade level. The different teaching contexts did not show a difference on TPACK confidence, but TPACK confidence may well be expressed in different ways for different teachers, which can be explored through for example the range and specific types of activities measured in the breadth scale.

As part of this survey I gathered examples of successful past uses of technology to support student learning. That data has not yet been explored, but I expect it to provide a rich supplemental data set that can further illuminate the relationship between the knowledge base represented by TPACK confidence and actual use of technology with students. This set includes examples of specific types of technology, the lesson goals or objectives, and information about the students for whom the lesson was designed.

A number of questions were raised by this dissertation that can be answered by studies using other methodologies. The broad definitions of "technology use" are in many ways unsatisfactory measures, as they are open to a wide range of interpretation by respondents. The success stories mentioned above will help to alleviate this concern, but they vary greatly across individuals and are difficult to compare. One way to address this concern would be through the use of hypothetical scenarios. These can be designed to explore not only the uses of new technologies, but also the process of choosing technologies for use in teaching.

Another problem with the current survey involved the reference points used by respondents to rate their own knowledge; the degree to which teachers agree with statements in the TPACK confidence scale may depend on their perception of the abilities of others. Through interviews, we may gain a clearer understanding of the role of perceptions and interpersonal influences on TPACK confidence. Interviews and observations may also allow us to surface evidence of pedagogical content knowledge, and to understand how teachers see the relationship between technology and PCK.

To answer the many questions about the role of computer access in the development of TPACK, it would be worthwhile to perform an experimental intervention in which teachers were given various levels of computer access. Although this might be difficult to do at scale, even a smaller, quasi-experimental study would give valuable insights into the relationship between computer access at school and teacher TPACK development. Another form of intervention study would also contribute important insights into the nature of learning partnerships and their impact on student experiences. An observational study of a lesson study group focused on technology use would provide insights into all links in the chain from teacher learning to student progress.

Conclusions

Better learning experiences for all students are the ultimate goal of research in educational technology use. This dissertation explored the nature of the TPACK confidence measure and its associations with important factors in the teachers' teaching and learning contexts, with the hope that findings would help build our understanding of the TPACK construct, as well as illuminate the path toward the best learning experiences in schools.

The results lead me to conclude that the TPACK framework is useful and important. Analyzing TPACK confidence provided insights into how to understand, and subsequently increase, teacher TPACK. The exploration of social learning networks across settings in teachers' learning ecologies suggested that efforts to raise TPACK might be most successful when supported by learning partners, especially those at the school site and in the education profession. The analyses further demonstrated that higher TPACK confidence is associated with higher levels of student access to the types of experiences that close the participation gap, prepare them with 21st century skills, and potentially provide powerful learning experiences. Continued study of the nature of TPACK and the conditions under which it develops is critical as we come to understand how teachers learn to use new technologies to support student learning.

APPENDIX A: SURVEY MEASURES

Section	Chapter 4	5	6	7	Items	Response	Sources	*Notes*
Confidence								
TPACK		X	X	X	I can teach lessons that appropriately combine mathematics, technologies and teaching approaches.	Strongly Disagree (1) to Strongly Agree (5)	Schmidt, et al. (2009) with modifications	*Given for each subject taught. 5 items averaged. Highest of all subjects used in analyses.*
		X	X	X	I can select technologies to use in my classroom that enhance what I teach and what students learn.			
		X	X	X	I can use strategies that combine math content, technologies, and teaching approaches that I learned about elsewhere, in my classroom.			
		X	X	X	I can provide leadership in helping others to coordinate the use of math content, technologies, and teaching approaches at my school and/or district.			
		X	X	X	I can choose technologies that enhance the math content for a lesson.			
TPK		X			I can choose technologies that enhance the teaching approaches for a lesson.	Strongly Disagree (1) to Strongly Agree (5)	Schmidt, et al. (2009) with modifications	*5 items averaged.*
		X			I can choose technologies that enhance students' learning for a lesson.			
		X			My experiences have caused me to think more deeply about how technologies could influence the teaching approaches I use in my classroom.			
		X			I am thinking critically about how to use technologies in my classroom.			
		X			I can adapt the use of the technologies that I learn about to different teaching activities.			
TCK		X			I know about technologies that I can use for understanding and doing mathematics.	Strongly Disagree (1) to Strongly Agree (5)	Schmidt, et al. (2009) with modifications	

Section	Chapter 4	5	6	7	Items	Response	Sources	*Notes*
PCK		X			I know how to select effective teaching approaches to guide student thinking and learning in mathematics.	Strongly Disagree (1) to Strongly Agree (5)	Schmidt, et al. (2009)	
TK		X			I know how to solve my own technical problems.	Strongly Disagree (1) to Strongly Agree (5)	Schmidt, et al. (2009)	*7 items averaged.*
		X			I can learn technology easily.			
		X			I keep up with important new technologies.			
		X			I frequently play around with technology.			
		X			I know about a lot of different technologies.			
		X			I have the technical skills I need to use technology.			
		X			I have had sufficient opportunities to work with different technologies.			
Internet Terms		X			JPEG	1= none 2=little 3=some 4=good 5=full	Hargittai (2005)	*27 items averaged. Missing replaced with mean.*
		X			frames			
		X			preference settings			
		X			newsgroups			
		X			PDF			
		X			refresh/ reload			
		X			advanced search			
		X			weblog			
		X			bookmark			
		X			bookmarklet			
		X			spyware			
		X			bcc (on e-mail)			
		X			blog			
		X			tagging			
		X			tabbed browsing			
		X			RSS			
		X			wiki			
		X			malware			
		X			social bookmarking			
		X			pod-casting			
		X			phishing			
		X			web feeds			
		X			firewall			
		X			cache			

Section	Chapter				Items	Response	Sources	*Notes*
	4	5	6	7				
		X			widget			
		X			favorites			
		X			torrent			
Experience								
Years teaching	X	X	X		Altogether, how many years have you worked as a teacher? (Please enter a numeral.)	open text response		*Recoded*
Activity breadth: personal and student					The following set of items asks about your experiences with technology outside the classroom. We'd like to know how many times you yourself have created the following types of products.	never; 1-2; 3-6; 7 or more times	Barron (2004) with modifications to update examples	*Items tallied for all 1+ (ever); 3+ (repeat) use for both student use and personal tasks.*
		X	X		Create a multimedia presentation (e.g., PowerPoint)			
		X	X		Write a computer program (code) using a computer language (e.g., C, Java, Visual Basic)			
		X	X		Make a publication, like a newsletter, using a desktop publishing program (e.g., PageMaker, Word, ComicLife)			
		X	X		Create your own newsgroup, blog, or discussion site on the Internet			
		X	X		Create a Web site (e.g., Dreamweaver, web, HTML)			
		X	X		Put a site on the Web so that other people could see it			
		X	X		Create a piece of art using an application (e.g., Photoshop, Illustrator, Kidpix)			
		X	X		Design a 2-d or 3-d model or drawing (e.g., CAD or ModelShop)			
		X	X		Build a robot or create an invention of any kind using digital technology			
		X	X		Use a simulation to model a real life situation or set of data			
		X	X		Build a database (e.g., Filemaker Pro, Microsoft Access)			

Section	Chapter 4	5	6	7	Items	Response	Sources	*Notes*
		X	X		Create a digital movie (e.g., iMovie or MovieMaker)			
		X	X		Create a computer game (e.g., Stagecast, GameStar, Scratch)			
		X	X		Create a piece of music (e.g., GarageBand, FruityLoops)			
		X	X		Create a spreadsheet, graph, or chart (e.g., Excel)			
		X	X		Create an animation (e.g., Flash, Alice, Scratch)			
Student Frequency		X	X		On average, how often do you plan for a typical student to use a computer during your class? Approximately...	Never, Less than Once a Month, 1-2 Times a Month, 1-2 Times a Week, 3 Times a Week+		*Follow-up Survey*
Personal Frequency					How often do you use Computers and/or the Internet for the following personal tasks?	Never, Less than Once a Month, Once a Month, 2-3 Times a Month, Once a Week, 2-3 Times a Week, Daily		*Items recoded for 1x/week and then tallied.*
			X		· Read or send e-mail			
			X		· Learn information about a topic that is of personal interest to me			
			X		· Talk to others online about a hobby			
			X		· Play games (on the computer, online, or on a game console)			
			X		· Work on your own digital media projects (including photos, movies, music)			
			X		· Edit/design your own blog / social networking page (e.g., Facebook, blogger)			

Section	Chapter 4	5	6	7	Items	Response	Sources	*Notes*
Resources								
Classroom Equip					What kinds of digital technology do you have access to in your classroom or where you teach? (Check all that apply. If you teach in several locations, check what you have access to anywhere. For number of computers, enter the highest number in any one place.)	Check=yes		
			X		· Desktop computers (enter number):	number		*Combined desktop with laptop #'s, then coded for 1+ (any) or 5+*
			X		· Laptop computers (enter number):	number		
	X		X		· Teacher computer (desktop)			
	X		X		· Teacher computer (laptop)			
	X				· Interactive whiteboard			
	X				· Television			
School equip					What kinds of digital technology can you sign up for or check out, to use with students? (Check all that apply.)			
			X		· Computer Lab (enter number of computers):	number		*Combined desktop with laptop #'s, then coded for 20+, 40+, 60+*
			X		· Laptop computers / cart (enter number):	number		
Learning Resources								
Important @ School					Which of the following are important resources in your school or district that support your learning how to use new technologies for teaching? (Check all that apply. Check only if this resource supports your use of technology for teaching.)	Check=yes	Tally	
			X		· Technology-related workshops/classes at my school or district			
			X		· Other forms of Professional Development which include technology			

Section	Chapter 4	5	6	7	Items	Response	Sources	*Notes*
			X		· Teaching profession publications			
			X		· Teaching with Technology publications			
			X		· Technology books or manuals			
			X		· Technology Magazines			
			X		· Recommendations for online articles, blogs, discussion threads, etc.			
			X		· Step-by-step tutorials / instructions prepared by school or district personnel			
			X		· School- or District-based online network related to technology			
			X		· Other school- or district-based online network			
			X		· A technology interest club (e.g., Photoshop)			
			X		· A non-technology interest club (e.g., photography)			
			X		· Other:			
Important					The following question asks for resources outside the school/district context.	Check=yes		
Outside			X		· Technology-related workshops/classes outside my school or district			
			X		· Other forms of outside Professional Development which include technology			
			X		· Teaching profession publications			
			X		· Teaching with Technology publications			
			X		· Technology books or manuals			
			X		· Technology Magazines			
			X		· Online articles, blogs, discussion threads, etc.			
			X		· Step-by-step tutorials / instructions			
			X		· Online network related to technology (e.g., Classroom 2.0)			
			X		· Other online network			
			X		· A technology interest			

Section	Chapter 4	5	6	7	Items	Response	Sources	*Notes*
					club (e.g., PhotoShop)			
			X		· A non-technology interest club (e.g., photography)			
			X		· Software help-menus			
			X		· Playing around on my own			
			X		· Playing computer games			
			X		· A community center computer lab			
			X		· Other:			
Available @ School					What resources are available in your school or district to support your own learning about technology? (Check all that apply. You do not have to have used them, but if you believe they are available to you, please mark them.)	Check=yes		
			X		Technology-related workshops/classes at my school or district			
			X		Other forms of professional development which include technology.			
			X		Teaching with technology publications			
			X		Technology books or manuals			
			X		Technology magazines			
			X		Recommendations for online articles, discussion threads, etc.			
			X		Step-by-step tutorials / instructions prepared by school or district personnel			
			X		School- or district-based online network (e.g., Ning)			
Learning Network					In this section we are interested in understanding what kinds of support teachers rely on when they learn to use new technologies in the classroom.			

Section	Chapter 4	5	6	7	Items	Response	Sources	*Notes*
			X	X	The following questions will ask you to identify people and materials in your life who support your learning about new technologies for teachers and students, inside and outside of school. You may use whatever code names or initials make sense to you -- we will not be trying to identify your learning partners, but it will help us to ask you more information about how they help you learn.	Open-response text field.		*Total number of names (excluding self) tallied*
Type/Breadth			X	X	· Teaches me how to use technology	Check= yes/up to 9 roles	Barron, Martin, Takeuchi, & Fithian, (2009) modified for teachers	*Based on previous research, we've identified the following roles that people play that can help one learn:*
			X	X	· Lends me resources to help me learn (e.g., books)			
			X	X	· Provides or helps secure funding for technology			
			X	X	· Demonstrates technology use in lessons			
			X	X	· Learns with me			
			X	X	· Explains how tech can impact students			
			X	X	· Pays me to learn to use technology (e.g., stipend, release time)			
			X	X	· Poses challenges for me to find answers to			
			X	X	· Connects me to other people to learn from			
Setting			X	X	· Spouse or significant other	Drop down choices		*Recoded to School, Professional, Outside, Unknown*
			X	X	· Other family member			
			X	X	· Friend			
			X	X	· Student			
			X	X	· School colleague: same subject area			
			X	X	· School colleague: outside my subject area			
			X	X	· Non-School Teacher Colleague: same subject area			

Section	Chapter 4	5	6	7	Items	Response	Sources	*Notes*
			X	X	· Non-School Teacher Colleague: outside my subject area			
			X	X	· School administrator			
			X	X	· School technology mentor / coordinator			
			X	X	· School technology support (IT)			
			X	X	· District administrator			
			X	X	· District technology mentor / coordinator			
			X	X	· District technology support (IT)			
			X	X	· Non-School Colleague, other profession			
			X	X	· Product technology support contact			
			X	X	· Other Internet resource / online contact			
			X	X	· None of the above			
Beliefs								
Technology		X			Technology increases productivity.	Strongly Disagree (1) to Strongly Agree (5)	Christensen & Knezek (2009 part 6)	
		X			Technologies provide different ways of accomplishing a given task.		Koehler & Mishra (2008)	
		X			Technology improves the overall quality of life.		C&K (2009 part 6)	
		X			Working with technology makes people feel isolated from each other.	Reverse coded.	C&K (2009 part 5)	
		X			Technology dehumanizes society by treating everyone as a number.	Reverse coded.	C&K (2009 part 5)	
		X			Technology is changing the world too rapidly.	Reverse coded.	C&K (2009 part 5)	
Technology - Pedagogy		X			All students should have an opportunity to learn [to use] technology in core academic classes.	Strongly Disagree (1) to Strongly Agree (5)	Christensen & Knezek (2009 part 9, modified.)	*School (EETT; Goals 2000)*
		X			Students work harder at their assignments when they use technology.		Russell, Bebell, O'Dwyer, & O'Connor, (2003)	*Engagement, Interest, & Motivation, & Effort*
		X			When using technology, students take more initiative outside of class time--doing		Becker, (2000)	

Section	Chapter 4	5	6	7	Items	Response	Sources	*Notes*
					extra research or polishing their work.			
		X			The use of technology increases student motivation for class.		C&K (2009 part 4)	
		X			The use of technology makes a lesson more interesting.		C&K (2009 part 4)	
		X			Students use technology in order to avoid doing more important school work	Reverse coded.	Becker (2000), Russell, Bebell, O'Dwyer, & O'Connor (2003)	
		X			Technologies encourage students to be lazy	Reverse coded.	Russell, Bebell, O'Dwyer, & O'Connor (2003)	
		X			Students get distracted by all the technology.	Reverse coded.	Williams, et al. (2000)	
		X			Students create better-looking products with technology than with other traditional media.		Russell, Bebell, O'Dwyer, & O'Connor (2003)	*Work Quality / Communication*
		X			Students using technology focus on the looks of their presentation at the expense of its academic content.	Reverse coded.		
		X			Today's students learn better with technology.			*Learning (Prensky 2001; Zucker 2008)*
		X			Technology helps students acquire new knowledge effectively.		Williams, et al. (2000)	
		X			Technology hinders creativity in students.	Reverse coded.	C&K (2009 part 9, reversed)	
Technology - Content		X			Technology allows new representations of [disciplinary] concepts and/or content.	Strongly Disagree (1) to Strongly Agree (5)		*New representations transform content (Cox, 2008)*
		X			Technology is irrelevant to doing [the discipline I teach].	Reverse coded.		*Use in [subject] (Cox, 2008)*
		X			New types of work in [the discipline I teach] have been made possible by technology.			*Generation of new content (Cox, 2008)*

Section	Chapter 4	5	6	7	Items	Response	Sources	*Notes*
		X			Professionals in [the discipline I teach] seldom use technology.	Reverse coded.		*Professional practices (e.g., EETT; Zucker, 2008)*
Technology – Pedagogy - Content		X			Technology provides better strategies for learning [subject].	Strongly Disagree (1) to Strongly Agree (5)	Niess (2006)	*Orientations toward teaching [subject] (Magnusson, Krajcik, & Borko, 1999)*
		X			Technology discourages students from learning to think more like [professionals in this discipline].	Reverse coded.		
		X			Technology distracts students from understanding [subject] concepts in a meaningful way.	Reverse coded.		*Student's understanding of specific [subject] topics*
		X			Technology helps students grasp difficult [subject] concepts [more easily].		Russell, Bebell, O'Dwyer, & O'Connor (2003)	
		X			Technology helps assess student learning of [subject] concepts better.			*Assessment in [subject]*
		X			Technology makes student misconceptions about [subject] concepts more difficult to detect.	Reverse coded.		
		X			Technology supports better instructional strategies for teaching [subject].			*Instructional strategies for teaching [subject]*
		X			Technology makes it more difficult to address the diverse needs of students in learning [subject].	Reverse coded.	Niess (2006)	
	X	X			Please indicate whether you agree or disagree with the following statement: "Digital resources such as classroom technology and Web-based programs help my students' academic achievement."	Agree strongly, Agree somewhat, Disagree somewhat, Disagree strongly	Gates	*Follow-up survey*

Section	Chapter				Items	Response	Sources	*Notes*
	4	5	6	7				
Teaching Context								
Grades			X		What grade(s) are you teaching this year?	Check all that apply. K-12, Other.		
Subjects			X		What subject(s) are you teaching for your main assignment this year?	Check all that apply.		
School					Which of the following best describes the school in which you teach?			
			X		· Public			*Collapsed to public/other*
			X		· Charter			
			X		· Private			
			X		· Other (please specify)			
School					Which of the following best describes the area where your school is located?	Check one.		
			X		· Inner City			
			X		· Urban			
			X		· Suburban			
			X		· Small Town			
			X		· Rural			
			X		· Other (please specify)			
School					Please describe the community served by your school. What percentage (approximately) of the students are	Forced sum to 100%		*High- and middle-income not included in these analyses*
			X		· Low-Income?			
School					Which of the following describe the school in which you teach?	Check all that apply.		
			X		· Recognized by the state as a successful school (Distinguished / Blue Ribbon / AAA)			
			X		· Receiving assistance to improve student achievement (Program Improvement / State Monitored / High Priority)			
			X		· Title 1			
			X		· Other			
			X		· None of the Above			

Section	Chapter 4	5	6	7	Items	Response	Sources	*Notes*
Class					Which of the following types of courses do you teach? (Check all that apply.)			
			X		· AP / IB / Pre-IB / Honors / GATE			
			X		· Remedial			
			X		· Special Education			
			X		· English Language Learners			
			X		· Regular Education			
Demographics								
	X	X			What is your gender? Male Female	Check one.		
	X	X			What year were you born?	Open response.		*Year subtracted from 2010*
					What is your race / ethnicity?	Check all that apply.		
	X				· Asian			
	X				· Black / African American			
	X				· Hispanic			
	X				· Native American			
	X				· Pacific Islander			
	X				· White/Caucasian			
	X				· Other			
					What was the last grade or level of school that you yourself completed?	Check one.		
	X				· Two-year college graduate			
	X				· Four-year college graduate			
	X				· Some graduate credits			
	X				· Master's completed			
	X				· Credits beyond master's			
	X				· Doctorate (Ph.D. / Ed.D.) completed			

APPENDIX B: SURVEYS

Intro

Welcome!

This is a study of National Board Certified teachers and how they decide whether to use new technologies with students. It will help us to understand the conditions under which accomplished teachers do -- and don't -- use new technologies; how better to design new technologies for schools; and how to support teachers' professional learning.

We will ask about

- your access to technology, at home and at school,
- the people and resources that support your learning about technology,
- your experience using technology at school and at home,
- and your beliefs about technology use.

Please answer honestly. Your unique perspective is important.

We expect this survey to take between 30 and 45 minutes to complete. If you leave the survey before finishing, your answers will be saved. To continue, return to the survey from the same computer any time within two weeks of starting it.

Thank you for your participation! As participants, we think it's important that you are the first to know what we learn from the study. We look forward to providing you with advance notice of the major results next year.

Click "Next >>" below for information about the study protocol.

---

and the fine print...

Choosing and Using Technology with Students

You are invited to participate in a research study at Stanford University on teaching with new technologies. We would like you to help us understand how teachers choose to use technologies with students in the classroom. As a National Board Certified Teacher, your insights into how technology impacts your work with students are extremely valuable. You will be asked to respond to questions related to your attitudes, experience, and reasoning about technology. We expect this survey to take between 30 and 45 minutes to complete.

Potential Risks and Benefits We don't anticipate any risks associated with participation in this study. It is possible that the reflection on your practice would be of benefit to you yourself. The results of this study will inform the future design of professional learning opportunities for teachers and better digital tools for teaching. We cannot and do not guarantee or promise that you will receive any benefits from this study. There will be no compensation for your participation in this study.

Rights of Participation Participation is entirely voluntary. You may choose not to answer any question and you may withdraw or discontinue participation at any time without consequence to you. Your individual privacy will be maintained in all published and written data resulting from the study.

Questions, Concerns, or Complaints If you have any questions, concerns or complaints about this research study, its procedures, risks and benefits, please don't hesitate to ask me. I can be reached at forssell@stanford.edu. If you are not satisfied with how this study is being conducted, or if you have any concerns, complaints, or general questions about the research or your rights as a participant, please contact the Stanford Institutional Review Board (IRB) to speak to someone independent of the research team at (650) 723-2480 or toll free at 1 (866) 680-2906. You can also write to the Stanford IRB, Stanford University, Stanford, CA 94305-5401.

Please print a copy of this page for your records.

To participate in the study, click on the "Next >>" button below.

Protocol Director: Karin Forssell, Faculty Sponsor: Dr. Brigid Barron
Approval Period: 04/23/2009 - 12/31/2999

Would you be willing to participate in a follow-up interview? We would like to understand the experiences of a few individual teachers, to gain insight into the stories behind the survey numbers. If selected, the interview would be conducted at your school during the next few months.

- Yes
- No

If yes, please provide contact information (name, e-mail and/or phone number).

If you would like us to send you advance notice of what we learn from the study, please provide your preferred mailing address or e-mail address.

Teaching?

Browser Meta Info

This question will not be displayed to the recipient.
Browser:
Version:
Operating System:
Screen Resolution:
Flash Version:
Java Support:
User Agent:

Do you currently teach at least part time in the classroom?

- Yes
- No

If not teaching

What grade(s) have you taught? (Check all that apply.)

- Kindergarten
- 1st grade
- 2nd grade
- 3rd grade
- 4th grade
- 5th grade
- 6th grade
- 7th grade
- 8th grade
- 9th grade
- 10th grade
- 11th grade
- 12th grade
- Other:

What subject(s) have you taught? (Check all that apply.)

- English/Language Arts
- Mathematics
- Social Studies
- Science
- Drama
- Health
- Home Economics
- Industrial Arts

- English Language Development
- Special Education
- Art
- Business
- Computers
- Library Media
- Music
- Physical Education
- World Languages
- Other:

How many years did you teach in the classroom? (Please enter a numeral.)

What is your current job title or description?

"Technology" is a broad concept that can mean many different things. For the purpose of these questions, the term technology/technologies refers to the digital tools we use such as computers, laptops, iPods, handhelds, response systems, interactive whiteboards, software applications, web sites, etc.

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Technology increases productivity.					
Technologies provide different ways of accomplishing a given task.					
Technology improves the overall quality of life.					
Working with technology makes people feel isolated from each other.					
Technology dehumanizes society by treating everyone as a number.					
Technology is changing the world too rapidly.					

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
All students should have an opportunity to learn to use technology at school.					
Students should learn to use technology outside of school.					
Students work harder at their assignments when they use technology.					
When using technology, students take more initiative outside of class time--doing extra research or polishing their work.					
The use of technology increases student motivation for class.					
	Strongly		Neither Agree		Strongly

	Disagree	Disagree	nor Disagree	Agree	Agree
The use of technology makes a lesson more interesting.	○	○	○	○	○
Students use technology in order to avoid doing more important school work	○	○	○	○	○
Technologies encourage students to be lazy.	○	○	○	○	○
Students get distracted by all the technology.	○	○	○	○	○
Students create better-looking products with technology than with other traditional media.	○	○	○	○	○
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Students using technology focus on the looks of their presentation at the expense of its academic content.	○	○	○	○	○
Today's students learn better with technology.	○	○	○	○	○
Technology helps students acquire new knowledge effectively.	○	○	○	○	○
Technology hinders creativity in students.	○	○	○	○	○

The following set of items asks about your experiences with technology outside the classroom. We'd like to know how many times you yourself have created the following types of products.

	You (personal)			
	Never	1-2 times	3-6 times	7+ times
Create a multimedia presentation (e.g., PowerPoint)	○	○	○	○
Write a computer program (code) using a computer language (e.g., C, Java, Visual Basic)	○	○	○	○
Make a publication, like a newsletter, using a desktop publishing program (e.g., PageMaker, Word, ComicLife)	○	○	○	○
Create your own newsgoup, blog, or discussion site on the Internet	○	○	○	○
Create a Web site (e.g., Dreamweaver, iWeb, HTML)	○	○	○	○
Put a site on the Web so that other people could see it	○	○	○	○
Create a piece of art using an application (e.g., Photoshop, Illustrator, Kidpix)	○	○	○	○
	Never	1-2 times	3-6 times	7+ times
Design a 2-d or 3-d model or drawing (e.g., CAD or ModelShop)	○	○	○	○
Build a robot or create an invention of any kind using digital technology	○	○	○	○
Use a simulation to model a real life situation or set of data	○	○	○	○
Build a database (e.g., Filemaker Pro, Microsoft Access)	○	○	○	○
Create a digital movie (e.g., iMovie or MovieMaker)	○	○	○	○
Create an animation (e.g., Flash, Alice, Scratch)	○	○	○	○
Create a computer game (e.g., Stagecast, GameStar, Scratch)	○	○	○	○
Create a piece of music (e.g., GarageBand, FruityLoops)	○	○	○	○
	Never	1-2 times	3-6 times	7+ times
Create a spreadsheet, graph, or chart (e.g., Excel)	○	○	○	○

If teaching

The following questions help us to understand your teaching context.

What grade(s) are you teaching this year? (Check all that apply.)

- Kindergarten
- 1st grade
- 2nd grade
- 3rd grade
- 4th grade
- 5th grade
- 6th grade
- 7th grade
- 8th grade
- 9th grade
- 10th grade
- 11th grade
- 12th grade
- Other: ______

What subject(s) are you teaching for your main assignment this year? (Check all that apply.)

- English/Language Arts
- Mathematics
- Social Studies
- Science
- English Language Development
- Special Education
- Art
- Business
- Computers
- Drama
- Health
- Home Economics
- Industrial Arts
- Library Media
- Music
- Physical Education
- World Languages
- Other: ______

Did you teach the same subject/grade level(s) last year?

- yes
- no, last year I taught: ______

Which of the following best describes the school in which you teach?

Public	Magnet	Charter	Private	Other (please specify): ______
○	○	○	○	○

Which of the following best describes the area where your school is located?

Inner city	Urban	Suburban	Small town	Rural	Other (please specify): ______
○	○	○	○	○	○

Please describe the community served by your school. What percentage (approximately) of the students are

	0	10	20	30	40	50	60	70	80	90	100
Affluent?											
Average?											
Low-income?											

Total:

Which of the following describe the school in which you teach? (Check all that apply.)

- ☐ Recognized by the state as a successful school (Distinguished / Blue Ribbon / AAA)
- ☐ Receiving assistance to improve student achievement (Program Improvement / State Monitored / High Priority)
- ☐ Title 1 (at least 40% of students in the free and reduced lunch program.)
- ☐ Other (please specify):
- ☐ None of the above

Which of the following types of courses do you teach? (Check all that apply. This question is about your courses, not the students. For example, if you teach a regular education course with some ELL students, check regular education.)

- ☐ AP / IB / Pre-IB / Honors / GATE
- ☐ Remedial
- ☐ Special Education
- ☐ English Language Learners
- ☐ Regular Education

Altogether, how many years have you worked as a teacher? (Please enter a numeral.)

School Access

"Technology" is a broad concept that can mean a lot of different things. Throughout this survey, we use the words "technology" and "technologies" to refer to digital equipment and applications. That is, the digital tools we use such as **computers, laptops, iPods, handhelds, response systems, interactive whiteboards, software applications, web sites**, etc.

The following questions ask about the equipment and learning resources available to you at school.

What kinds of digital technology do you have access to **in your classroom** or **where you teach**? (Check all that apply. If you teach in several locations, check what you have access to anywhere. For number of computers, enter the highest number in any one place.)

☐ Desktop computers (enter number):	☐ Teacher computer (desktop)
☐ Laptop computers (enter number):	☐ Teacher computer (laptop)
☐ Digital camera(s)	☐ Handheld computer for teacher
☐ Digital video camera(s)	☐ Handheld computers for students
☐ Digital music / MP3 player(s)	☐ Student Response System (clickers)
☐ Document camera	☐ Scanner
☐ LCD projector	☐ Printer
☐ Interactive whiteboard	☐ Other (please specify):
☐ Television	

What kinds of digital technology can you **sign up for** or **check out**, to use with students? (Check all that apply.)

- Computer Lab (enter number of computers):
- Laptop computers / cart (enter number):
- Digital camera(s)
- Digital video camera(s)
- Digital music / MP3 player(s)
- Document camera
- LCD projector
- Interactive whiteboard
- Television
- Handheld computers for students
- Student Response System (clickers)
- Scanner
- Printer
- Other (please specify):

What resources are **available in your school or district** to support your own learning about technology? (Check all that apply. You do not have to have used them, but if you believe they are available to you, please mark them.)

- Technology-related workshops/classes at my school or district
- Other forms of professional development which include technology.
- Teaching with technology publications
- Technology books or manuals
- Technology magazines
- Recommendations for online articles, discussion threads, etc.
- Step-by-step tutorials / instructions prepared by school or district personnel
- School- or district-based online network (e.g., Ning)
- School technology mentor
- District technology mentor
- School IT support
- District IT support
- A technology interest club
- Other:

Learning Resources - people

LEARNING RESOURCES

In this section we are interested in understanding what kinds of support teachers rely on when they learn to use new technologies in the classroom. Based on previous research, we've identified the following roles that people play that can help one learn:

- Teaches me how to use technology
- Lends me resources to help me learn (e.g. books)
- Provides or helps secure funding for technology
- Demonstrates technology use in lessons
- Learns with me
- Explains how tech can impact students
- Pays me to learn to use technology (e.g. stipend, release time)
- Poses challenges for me to find answers to
- Connects me to other people to learn from

The following questions will ask you to identify people and materials in your life who support your learning about new technologies for teachers and students, inside and outside of school. You may use whatever code names or initials make sense to you -- we will not be trying to identify your learning partners, but it will help us to ask you more information about how they help you learn.

Please list important people (as many as you like) who **support your learning to use digital technologies with students**. Think about people inside and outside of school, teachers and non-teachers. You may use code names or initials -- we are not interested in their identities, but it will help us to ask you more information about how they help you learn. You do not have to fill in all the lines.

	code name or intitials	How does this person support your learning? (Check all that apply.)								
		Teaches me how to use technology	Lends me resources to help me learn (e.g., books)	Provides or helps secure funding for technology	Demonstrates technology use in lessons	Learns with me	Explains how tech can impact students	Pays me to learn to use technology (e.g., stipend, release time)	Poses challenges for me to find answers to	Connects me to other people to learn from
Person 1		☐	☐	☐	☐	☐	☐	☐	☐	☐
Person 2		☐	☐	☐	☐	☐	☐	☐	☐	☐
Person 3		☐	☐	☐	☐	☐	☐	☐	☐	☐
Person 4		☐	☐	☐	☐	☐	☐	☐	☐	☐
Person 5		☐	☐	☐	☐	☐	☐	☐	☐	☐
Person 6		☐	☐	☐	☐	☐	☐	☐	☐	☐
Person 7		☐	☐	☐	☐	☐	☐	☐	☐	☐
Person 8		☐	☐	☐	☐	☐	☐	☐	☐	☐

Would you like to enter more people?

- ◯ Yes, I'd like to enter more lines.
- ◯ No, I'm finished.

Please list important people (as many as you like) who **support your learning to use digital technologies with students**. Think about people inside and outside of school, teachers and non-teachers. You may use code names or initials -- we are not interested in their identities, but it will help us to ask you more information about how they help you learn. You do not have to fill in all the lines.

	code name or intitials	How does this person support your learning? (Check all that apply.)								
		Teaches me how to use technology	Lends me resources to help me learn (e.g. books)	Provides or helps secure funding for technology	Demonstrates technology use in lessons	Learns with me	Explains how tech can impact students	Pays me to learn to use technology (e.g. stipend, release time)	Poses challenges for me to find answers to	Connects me to other people to learn from
Person 9		☐	☐	☐	☐	☐	☐	☐	☐	☐
Person 10		☐	☐	☐	☐	☐	☐	☐	☐	☐
Person 11		☐	☐	☐	☐	☐	☐	☐	☐	☐
Person 12		☐	☐	☐	☐	☐	☐	☐	☐	☐
Person 13		☐	☐	☐	☐	☐	☐	☐	☐	☐
Person 14		☐	☐	☐	☐	☐	☐	☐	☐	☐
Person 15		☐	☐	☐	☐	☐	☐	☐	☐	☐

Person 16

How do you best describe your relationship to each of the people who support you in learning to use technology for teaching?

	Relationship
${q://QID142#1/ChoiceTextEntryValue/1/1}	
${q://QID142#1/ChoiceTextEntryValue/2/1}	
${q://QID142#1/ChoiceTextEntryValue/3/1}	
${q://QID142#1/ChoiceTextEntryValue/4/1}	
${q://QID142#1/ChoiceTextEntryValue/5/1}	
${q://QID142#1/ChoiceTextEntryValue/6/1}	
${q://QID142#1/ChoiceTextEntryValue/7/1}	
${q://QID142#1/ChoiceTextEntryValue/8/1}	

How do you best describe your relationship to each of the people who support you in learning to use technology for teaching?

	Relationship
${q://QID144#1/ChoiceTextEntryValue/1/1}	
${q://QID144#1/ChoiceTextEntryValue/2/1}	
${q://QID144#1/ChoiceTextEntryValue/3/1}	
${q://QID144#1/ChoiceTextEntryValue/4/1}	
${q://QID144#1/ChoiceTextEntryValue/5/1}	
${q://QID144#1/ChoiceTextEntryValue/6/1}	
${q://QID144#1/ChoiceTextEntryValue/7/1}	
${q://QID144#1/ChoiceTextEntryValue/8/1}	

Learning Resources - Materials

Which of the following are **important resources in your school or district** that support your learning how to use new technologies for teaching? (Check all that apply. Check only if this resource supports your use of technology for teaching.)

- Technology-related workshops/classes at my school or district
- Other forms of Professional Development which include technology
- Teaching profession publications
- Teaching with Technology publications
- Technology books or manuals
- Technology Magazines
- Recommendations for online articles, blogs, discussion
- Step-by-step tutorials / instructions prepared by school or district personnel
- School- or District-based online network related to technology
- Other school- or district-based online network
- A technology interest club (e.g., Photoshop)
- A non-technology interest club (e.g., photography)
- Other:

- Recommendations for online articles, blogs, discussion threads, etc.

Which of the following are **important resources outside your school or district** that support your learning how to use new technologies for teaching? (Check all that apply. Check only if this resource supports your use of technology for teaching.)

- Technology-related workshops/classes outside my school or district
- Other forms of outside Professional Development which include technology
- Teaching profession publications
- Teaching with Technology publications
- Technology books or manuals
- Technology Magazines
- Online articles, blogs, discussion threads, etc.
- Step-by-step tutorials / instructions
- Online network related to technology (e.g., Classroom 2.0)
- Other online network
- A technology interest club (e.g., PhotoShop)
- A non-technology interest club (e.g., photography)
- Software help-menus
- Playing around on my own
- Playing computer games
- A community center computer lab
- Other: ____

Success

The next section asks you to reflect on two times within the last two years when you chose to use digital technologies to enhance student learning -- one successful, and one unsuccessful.

SUCCESSFUL: Please think of a time within the last two years when you used a digital technology with students, and you considered it **successful as a tool to enhance your students' learning in your subject area**. This could be a piece of equipment, a piece of software, or a web site.

Timing

This page timer will not be displayed to the recipient.

First Click: 0 seconds.

Last Click: 0 seconds.

Page Submit: 0 seconds.

Click Count: 0 clicks.

Details of the lesson:

Grade and subject area ____

Lesson topic ____

What was the technology? ____

What was the activity? ____

What was your **learning objective** for this lesson? (please specify the particular concept, skill, or way of thinking)

____

Why was the technology integration successful? **How** did using the technology impact student learning? (features, capabilities, affordances)

Students participating in this lesson were:
(Check all that apply.)

- High-achieving
- Average
- Low-achieving
- Other (please specify):
- Special Ed
- Gifted / Talented (GATE)
- English Language Learners

How did you find out about this technology?

What circumstances convinced you to try it?

Would you use this technology again in the future?

yes no

Unsuccessful

NOT SUCCESSFUL: Please think of a time within the last two years when you used a digital technology with students, and you considered it **unsuccessful as a tool to enhance your students' learning in your subject area**. This could be a piece of equipment, a piece of software, or a web site.

Timing

This page timer will not be displayed to the recipient.

First Click: 0 seconds.

Last Click: 0 seconds.

Page Submit: 0 seconds.

Click Count: 0 clicks.

Details of the lesson:

Grade and subject area

Lesson topic

What was the technology?

What was the activity?

What was your **learning objective** for this lesson? (please specify the particular concept, skill, or way of thinking)

Why was the technology integration unsuccessful, and **how** did using the technology impact student learning?

Students participating in this lesson were:
(Check all that apply.)

- ☐ High-achieving
- ☐ Special Ed
- ☐ Average
- ☐ Gifted / Talented (GATE)
- ☐ Low-achieving
- ☐ English Language Learners
- ☐ Other (please specify):

How did you find out about this technology?

What circumstances convinced you to try it?

Would you use this technology again in the future?

yes	no
○	○

TPC Beliefs

BELIEFS

These questions ask about your beliefs about technology and its relationship to teaching.

"Technology" is a broad concept that can mean a lot of different things. For the purpose of these questions, technology is referring to digital technology/technologies. That is, the digital tools we use such as **computers, laptops, iPods, handhelds, response systems, interactive whiteboards, software applications, web sites**, etc.

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Working with technology makes people feel isolated from each other.	○	○	○	○	○
Technology is changing the world too rapidly.	○	○	○	○	○
Technologies provide different ways of accomplishing a given task.	○	○	○	○	○
Technology improves the overall quality of life.	○	○	○	○	○
Technology dehumanizes society by treating everyone as a number.	○	○	○	○	○
Technology increases productivity.	○	○	○	○	○

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
The use of technology increases student motivation for class.	○	○	○	○	○
Students create better-looking products with technology than with other traditional media.	○	○	○	○	○
All students should have an opportunity to learn to use technology in core academic classes.	○	○	○	○	○
Students should learn to use technology outside of core academic classes.	○	○	○	○	○
Today's students learn better with technology.	○	○	○	○	○
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Technologies encourage students to be lazy.	○	○	○	○	○
Students use technology in order to avoid doing more important school work.	○	○	○	○	○
The use of technology makes a lesson more interesting.	○	○	○	○	○
Students using technology focus on the looks of their presentation at the expense of its academic content.	○	○	○	○	○
When using technology, students take more initiative outside of class time (e.g., doing extra research or polishing their work).	○	○	○	○	○
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Technology helps students acquire new knowledge effectively.	○	○	○	○	○
Technology hinders creativity in students.	○	○	○	○	○
Students get distracted by all the technology.	○	○	○	○	○
Students work harder at their assignments when they use technology.	○	○	○	○	○

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Scientists seldom use technology.	○	○	○	○	○
Technology is irrelevant to doing science.	○	○	○	○	○
New types of work in the sciences have been made possible by technology.	○	○	○	○	○
Technology creates new ways of exploring scientific questions.	○	○	○	○	○

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Technology is irrelevant to writing.	○	○	○	○	○
Technology creates new ways of exploring text.	○	○	○	○	○
New types of writing work have been made possible by technology.	○	○	○	○	○
Writers seldom use technology.	○	○	○	○	○

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Technology is irrelevant to doing mathematics.	○	○	○	○	○
Mathematicians seldom use technology.	○	○	○	○	○
Technology creates new ways of exploring mathematics.	○	○	○	○	○
New types of work in mathematics have been made possible by technology.	○	○	○	○	○

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Social scientists seldom use technology.	○	○	○	○	○
New types of work in the social sciences have been made possible by technology.	○	○	○	○	○
Technology creates new ways of exploring social science questions.	○	○	○	○	○
Technology is irrelevant to doing work in the social sciences.	○	○	○	○	○

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
New types of work related to multiple languages have been made possible by technology.	○	○	○	○	○

Technology creates new ways of exploring new languages.					
Technology is irrelevant to speaking another language.					
Professionals working with multiple languages seldom use technology.					

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Technology creates new ways of exploring artistic expression.					
Technology is irrelevant to doing work in the arts.					
Visual and performing artisits seldom use technology.					
New types of work in the arts have been made possible by technology.					

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Business people seldom use technology.					
Technology creates new ways of exploring business challenges.					
New types of work in business have been made possible by technology.					
Technology is irrelevant to doing work in business.					

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Technology creates new ways of exploring industrial challenges.					
Technology is irrelevant to doing work in industry.					
People in industry seldom use technology.					
New types of work in industry have been made possible by technology.					

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Technology is irrelevant to doing work in the discipline I teach.					
Technology creates new ways of exploring concepts in the discipline I teach.					
New types of work in the discipline I teach have been made possible by technology.					
People in the discipline I teach seldom use technology.					

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Technology makes student misconceptions about scientific concepts more difficult to detect.	○	○	○	○	○
Technology helps students grasp difficult scientific concepts more easily.	○	○	○	○	○
Technology helps assess student learning of scientific concepts better.	○	○	○	○	○
Technology distracts students from understanding scientific concepts in a meaningful way.	○	○	○	○	○
Technology supports better instructional strategies for teaching science.	○	○	○	○	○
Technology makes it more difficult to address the diverse needs of students in learning science.	○	○	○	○	○
Technology provides better strategies for learning science.	○	○	○	○	○
Using technology discourages students from thinking like scientists.	○	○	○	○	○

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Technology provides better strategies for learning math.	○	○	○	○	○
Using technology discourages students from thinking like mathematicians.	○	○	○	○	○
Technology distracts students from understanding mathematical concepts in a meaningful way.	○	○	○	○	○
Technology helps students grasp difficult mathematical concepts more easily.	○	○	○	○	○
Technology helps assess student learning of mathematical concepts better.	○	○	○	○	○
Technology makes student misconceptions about mathematical concepts more difficult to detect.	○	○	○	○	○
Technology supports better instructional strategies for teaching math.	○	○	○	○	○
Technology makes it more difficult to address the diverse needs of students in learning math.	○	○	○	○	○

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Technology distracts students from understanding language arts concepts in a meaningful way.	○	○	○	○	○
Technology supports better instructional strategies for teaching English/Language	○	○	○	○	○

Arts.					
Technology helps students grasp difficult language arts concepts more easily.	○	○	○	○	○
Using technology discourages students from thinking like writers.	○	○	○	○	○
Technology makes it more difficult to address the diverse needs of students in learning English/Language Arts.	○	○	○	○	○
Technology provides better strategies for learning English/Language Arts.	○	○	○	○	○
Technology helps assess student learning of language arts concepts better.	○	○	○	○	○
Technology makes student misconceptions about language arts concepts more difficult to detect.	○	○	○	○	○

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Technology distracts students from understanding social studies concepts in a meaningful way.	○	○	○	○	○
Technology supports better instructional strategies for teaching social studies.	○	○	○	○	○
Technology helps assess student learning of social studies concepts better.	○	○	○	○	○
Technology provides better strategies for learning social studies.	○	○	○	○	○
Technology helps students grasp difficult social studies concepts more easily.	○	○	○	○	○
Technology makes student misconceptions about social studies concepts more difficult to detect.	○	○	○	○	○
Using technology discourages students from thinking like social scientists.	○	○	○	○	○
Technology makes it more difficult to address the diverse needs of students in learning social studies.	○	○	○	○	○

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Technology helps assess student learning of second language concepts better.	○	○	○	○	○
Technology supports better instructional strategies for teaching a new language.	○	○	○	○	○
Technology provides better strategies for learning a new language.	○	○	○	○	○
Using technology discourages students from thinking like speakers of the target language.	○	○	○	○	○
Technology makes student misconceptions about second language concepts more difficult to detect.	○	○	○	○	○
Technology helps students grasp difficult second language concepts more easily.	○	○	○	○	○

Technology distracts students from understanding second language concepts in a meaningful way.	○	○	○	○	○
Technology makes it more difficult to address the diverse needs of students in learning a new language.	○	○	○	○	○

To what extent do you agree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Technology distracts students from understanding artistic concepts in a meaningful way.	○	○	○	○	○
Technology makes it more difficult to address the diverse needs of students in learning music, art, or drama.	○	○	○	○	○
Using technology discourages students from thinking like artists.	○	○	○	○	○
Technology helps students grasp difficult artistic concepts more easily.	○	○	○	○	○
Technology helps assess student learning of artistic concepts better.	○	○	○	○	○
Technology provides better strategies for learning music, art, or drama.	○	○	○	○	○
Technology makes student misconceptions about artistic concepts more difficult to detect.	○	○	○	○	○
Technology supports better instructional strategies for teaching music, art, or drama.	○	○	○	○	○

PCK, TPK, TPACK

KNOWLEDGE

In the following questions we ask that you rate your ability to choose and use digital technology.

"Technology" is a broad concept that can mean a lot of different things. For the purpose of these questions, technology is referring to digital technology/technologies. That is, the digital tools we use such as **computers, laptops, iPods, handhelds, response systems, interactive whiteboards, software applications, web sites**, etc.

To what extent do you agree or disagree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I can choose technologies that enhance the teaching approaches for a lesson.	○	○	○	○	○
I can choose technologies that enhance students' learning for a lesson.	○	○	○	○	○
My experiences have caused me to think more deeply about how technologies could influence the teaching approaches I use in my classroom.	○	○	○	○	○
I am thinking critically about how to use technologies in my classroom.	○	○	○	○	○
I can adapt the use of the technologies that I learn about to different teaching activities.	○	○	○	○	○

To what extent do you agree or disagree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I know how to select effective teaching approaches to guide student thinking and learning in mathematics.	○	○	○	○	○
I know about technologies that I can use for understanding and doing mathematics.	○	○	○	○	○
I can teach lessons that appropriately combine mathematics, technologies and teaching approaches.	○	○	○	○	○
I can select technologies to use in my classroom that enhance what I teach and what students learn.	○	○	○	○	○
I can use strategies that combine math content, technologies, and teaching approaches that I learned about elsewhere, in my classroom.	○	○	○	○	○
I can provide leadership in helping others to coordinate the use of math content, technologies, and teaching approaches at my school and/or district.	○	○	○	○	○
I can choose technologies that enhance the math content for a lesson.	○	○	○	○	○

To what extent do you agree or disagree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I know how to select effective teaching approaches to guide student thinking and learning in language arts.	○	○	○	○	○
I know about technologies that I can use for understanding and doing language arts.	○	○	○	○	○
I can teach lessons that appropriately combine literacy, technologies and teaching approaches.	○	○	○	○	○
I can select technologies to use in my classroom that enhance what I teach and what students learn.	○	○	○	○	○
I can use strategies that combine language arts content, technologies, and teaching approaches that I learned about elsewhere, in my classroom.	○	○	○	○	○
I can provide leadership in helping others to coordinate the use of language arts content, technologies, and teaching approaches at my school and/or district.	○	○	○	○	○
I can choose technologies that enhance the language arts content for a lesson.	○	○	○	○	○

To what extent do you agree or disagree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I know how to select effective teaching approaches to guide student thinking and learning in social studies.	○	○	○	○	○
I know about technologies that I can use for understanding and doing social science.	○	○	○	○	○
I can teach lessons that appropriately combine social studies, technologies and teaching approaches.	○	○	○	○	○
I can select technologies to use in my classroom that enhance what I teach and what students learn.	○	○	○	○	○

I can use strategies that combine social studies content, technologies, and teaching approaches that I learned about elsewhere, in my classroom.	○	○	○	○	○
I can provide leadership in helping others to coordinate the use of social studies content, technologies, and teaching approaches at my school and/or district.	○	○	○	○	○
I can choose technologies that enhance the social studies content for a lesson.	○	○	○	○	○

To what extent do you agree or disagree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I know how to select effective teaching approaches to guide student thinking and learning in science.	○	○	○	○	○
I know about technologies that I can use for understanding and doing science.	○	○	○	○	○
I can teach lessons that appropriately combine science, technologies and teaching approaches.	○	○	○	○	○
I can select technologies to use in my classroom that enhance what I teach and what students learn.	○	○	○	○	○
I can use strategies that combine science content, technologies, and teaching approaches that I learned about elsewhere, in my classroom.	○	○	○	○	○
I can provide leadership in helping others to coordinate the use of science content, technologies, and teaching approaches at my school and/or district.	○	○	○	○	○
I can choose technologies that enhance the science content for a lesson.	○	○	○	○	○

To what extent do you agree or disagree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I know how to select effective teaching approaches to guide student thinking and learning in language acquisition.	○	○	○	○	○
I know about technologies that I can use for understanding and producing language.	○	○	○	○	○
I can teach lessons that appropriately combine language acquisition, technologies and teaching approaches.	○	○	○	○	○
I can select technologies to use in my classroom that enhance what I teach and what students learn.	○	○	○	○	○
I can use strategies that combine second language content, technologies, and teaching approaches that I learned about elsewhere, in my classroom.	○	○	○	○	○
I can provide leadership in helping others to coordinate the use of second language content, technologies, and teaching approaches at my school and/or district.	○	○	○	○	○
I can choose technologies that enhance the second language content for a lesson.	○	○	○	○	○

To what extent do you agree or disagree with the following statements?

Neither

	Strongly Disagree	Disagree	Agree nor Disagree	Agree	Strongly Agree
I know how to select effective teaching approaches to guide student thinking and learning in art, music, or drama.	○	○	○	○	○
I know about technologies that I can use for understanding and practicing art, music, or drama.	○	○	○	○	○
I can teach lessons that appropriately combine concepts in the arts, technologies and teaching approaches.	○	○	○	○	○
I can select technologies to use in my classroom that enhance what I teach and what students learn.	○	○	○	○	○
I can use strategies that combine arts content, technologies, and teaching approaches that I learned about elsewhere, in my classroom.	○	○	○	○	○
I can provide leadership in helping others to coordinate the use of arts content, technologies, and teaching approaches at my school and/or district.	○	○	○	○	○
I can choose technologies that enhance the arts content for a lesson.	○	○	○	○	○

To what extent do you agree or disagree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I know how to select effective teaching approaches to guide student thinking and learning about industry.	○	○	○	○	○
I know about technologies that I can use for understanding and practicing industry skills.	○	○	○	○	○
I can teach lessons that appropriately combine concepts from industry, technologies and teaching approaches.	○	○	○	○	○
I can select technologies to use in my classroom that enhance what I teach and what students learn.	○	○	○	○	○
I can use strategies that combine skills content, technologies, and teaching approaches that I learned about elsewhere, in my classroom.	○	○	○	○	○
I can provide leadership in helping others to coordinate the use of skills content, technologies, and teaching approaches at my school and/or district.	○	○	○	○	○
I can choose technologies that enhance the skills content for a lesson.	○	○	○	○	○

To what extent do you agree or disagree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I know how to select effective teaching approaches to guide student thinking and learning in my subject area.	○	○	○	○	○
I know about technologies that I can use for practicing the discipline I teach.	○	○	○	○	○
I can teach lessons that appropriately combine content, technologies and teaching approaches.	○	○	○	○	○
I can select technologies to use in my classroom that enhance what I teach and what students learn.	○	○	○	○	○
I can use strategies that combine content, technologies, and teaching approaches that I learned about elsewhere,	○	○	○	○	○

in my classroom.					
I can provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches at my school and/or district.	○	○	○	○	○
I can choose technologies that enhance the content for a lesson.	○	○	○	○	○

Experience

EXPERIENCE

Almost finished! The following set of items asks about your experiences with technology in and outside the classroom.

We'd like to know how many times you yourself have ever created the following types of products, and how many times you have ever asked students to do these activities in your class(es).

	Your students (in class)				You (personal)			
	Never	1-2 times	3-6 times	7+ times	Never	1-2 times	3-6 times	7+ times
Create a multimedia presentation (e.g., PowerPoint)	○	○	○	○	○	○	○	○
Write a computer program (code) using a computer language (e.g., C, Java, Visual Basic)	○	○	○	○	○	○	○	○
Make a publication, like a newsletter, using a desktop publishing program (e.g., PageMaker, Word, ComicLife)	○	○	○	○	○	○	○	○
Create your own newsgoup, blog, or discussion site on the Internet	○	○	○	○	○	○	○	○
Create a Web site (e.g., Dreamweaver, iWeb, HTML)	○	○	○	○	○	○	○	○
Put a site on the Web so that other people could see it	○	○	○	○	○	○	○	○
Create a piece of art using an application (e.g., Photoshop, Illustrator, Kidpix)	○	○	○	○	○	○	○	○
	Never	1-2 times	3-6 times	7+ times	Never	1-2 times	3-6 times	7+ times
Design a 2-d or 3-d model or drawing (e.g., CAD, Google SketchUp, or ModelShop)	○	○	○	○	○	○	○	○
Build a robot or create an invention of any kind using digital technology	○	○	○	○	○	○	○	○
Use a simulation to model a real life situation or set of data	○	○	○	○	○	○	○	○
Build a database (e.g., Filemaker Pro, Microsoft Access)	○	○	○	○	○	○	○	○
Create a digital movie (e.g., iMovie or MovieMaker)	○	○	○	○	○	○	○	○
Create an animation (e.g., Flash, Alice, Scratch)	○	○	○	○	○	○	○	○
Create a computer game (e.g., Stagecast, GameStar, Scratch)	○	○	○	○	○	○	○	○
Create a piece of music (e.g., GarageBand, FruityLoops)	○	○	○	○	○	○	○	○
	Never	1-2 times	3-6 times	7+ times	Never	1-2 times	3-6 times	7+ times
Create a spreadsheet, graph, or chart (e.g., Excel)	○	○	○	○	○	○	○	○

Home access & use

The following questions ask you about your use of computers and other digital technologies in your personal life.

How many working computers do you (and your family) have at home?

0	1	2	3	4 or more
○	○	○	○	○

What other kinds of digital technology do you have at home? (Check all that apply.)

- ☐ mobile phone
- ☐ digital camera
- ☐ Scanner
- ☐ digital video camera
- ☐ Digital music player (MP3)
- ☐ Printer
- ☐ Game console (e.g., Playstation, XBox)
- ☐ Other (please specify): ______

What sort of Internet access do you have at home? (Choose one.)

- ○ I do not have Internet access at home
- ○ I do have Internet access at home, but I don't know what sort
- ○ Dial-up
- ○ Broadband / DSL / Cable / Satellite

How many people use your computer?

- ○ 1: I have at least one computer that I alone use.
- ○ 2: I share my computer with one other person.
- ○ 3+: I share my computer with two or more others.

Do you have a computer that you call your own (you are the main user; others have to ask you for permission to use it)?

- ○ Yes
- ○ No

How old were you when you first used a computer? (Please enter a numeral.)

______

How often do you use Computers and/or the Internet for the following personal tasks?

	Never	Less than Once a Month	Once a Month	2-3 Times a Month	Once a Week	2-3 Times a Week	Daily
Read or send e-mail	○	○	○	○	○	○	○
Learn information about a topic that is of personal interest to me	○	○	○	○	○	○	○
Talk to others online about a hobby	○	○	○	○	○	○	○
Play games (on the computer, online, or on a game console)	○	○	○	○	○	○	○

Work on your own digital media projects (including photos, movies, music)	○	○	○	○	○	○	○
Edit/design your own blog / social networking page (e.g., Facebook, blogger)	○	○	○	○	○	○	○

Internet terms

These questions ask about your familiarity with technology.

How familiar are you with the following computer and Internet-related terms?
"None" represents "no understanding" and "Full" represents "full understanding" of the term.

	None	Little	Some	Good	Full
JPEG	○	○	○	○	○
frames	○	○	○	○	○
preference settings	○	○	○	○	○
newsgroups	○	○	○	○	○
PDF	○	○	○	○	○
refresh/ reload	○	○	○	○	○
advanced search	○	○	○	○	○
proxypod	○	○	○	○	○
	None	Little	Some	Good	Full
weblog	○	○	○	○	○
JFW	○	○	○	○	○
bookmark	○	○	○	○	○
bookmarklet	○	○	○	○	○
spyware	○	○	○	○	○
bcc (on e-mail)	○	○	○	○	○
blog	○	○	○	○	○
tagging	○	○	○	○	○
	None	Little	Some	Good	Full
tabbed browsing	○	○	○	○	○
RSS	○	○	○	○	○
wiki	○	○	○	○	○
malware	○	○	○	○	○
social bookmarking	○	○	○	○	○
pod-casting	○	○	○	○	○
phishing	○	○	○	○	○
web feeds	○	○	○	○	○
	None	Little	Some	Good	Full
firewall	○	○	○	○	○
filtibly	○	○	○	○	○

cache	○	○	○	○	○
widget	○	○	○	○	○
favorites	○	○	○	○	○
torrent	○	○	○	○	○

TK

Again, "Technology" is a broad concept that can mean a lot of different things. For the purpose of these questions, technology is referring to digital technology/technologies. That is, the digital tools we use such as **computers, laptops, iPods, handhelds, response systems, interactive whiteboards, software applications, web sites**, etc.

To what extent do you agree or disagree with the following statements?

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I know how to solve my own technical problems.	○	○	○	○	○
I can learn technology easily.	○	○	○	○	○
I keep up with important new technologies.	○	○	○	○	○
I frequently play around with technology.	○	○	○	○	○
I know about a lot of different technologies.	○	○	○	○	○
I have the technical skills I need to use technology.	○	○	○	○	○
I have had sufficient opportunities to work with different technologies.	○	○	○	○	○

Demographics

Finally, the following questions are used for describing the teachers who participate in this study. They help us to understand whether the participants in this study reflect the characteristics of teachers in California.

What year were you born?

What is your gender?

○ Male

○ Female

What is your race / ethnicity? (Check all that apply.)

Asian	Black / African American	Hispanic	Native American	Pacific Islander	White/Caucasian	Other
☐	☐	☐	☐	☐	☐	☐

What was the last grade or level of school that you yourself completed?

- Two-year college graduate
- Four-year college graduate
- Some graduate credits
- Master's completed
- Credits beyond master's
- Doctorate (Ph.D. / Ed.D.) completed

What year did you earn your teaching credential?

In what area did you achieve National Board Certification?

End

That's it. We very much appreciate your participation in this study! If there's anything you'd like to ask or say, feel free. Is there anything else you think we should know about you?

Thank you so much!

Intro

Dear National Board Certified Teachers,

Thank you again for your help as I try to understand how accomplished teachers use technologies to improve student outcomes.

Warmly,

Karin Forssell, NBCT '03

Click "Next >>" below for a reminder about the study protocol.

a few reminders...

Choosing and Using Technology with Students

You are invited to participate in a research study at Stanford University on teaching with new technologies. We would like you to help us understand how teachers choose to use technologies with students in the classroom. As a National Board Certified Teacher, your insights into how technology impacts your work with students are extremely valuable. You will be asked to respond to questions related to your attitudes, experience, and reasoning about technology. We expect this survey to take between 30 and 45 minutes to complete.

Potential Risks and Benefits We don't anticipate any risks associated with participation in this study. It is possible that the reflection on your practice would be of benefit to you yourself. The results of this study will inform the future design of professional learning opportunities for teachers and better digital tools for teaching. We cannot and do not guarantee or promise that you will receive any benefits from this study. There will be no compensation for your participation in this study.

Rights of Participation Participation is entirely voluntary. You may choose not to answer any question and you may withdraw or discontinue participation at any time without consequence to you. Your individual privacy will be maintained in all published and written data resulting from the study.

Questions, Concerns, or Complaints If you have any questions, concerns or complaints about this research study, its procedures, risks and benefits, please don't hesitate to ask me. I can be reached at forssell@stanford.edu. If you are not satisfied with how this study is being conducted, or if you have any concerns, complaints, or general questions about the research or your rights as a participant, please contact the Stanford Institutional Review Board (IRB) to speak to someone independent of the research team at (650) 723-2480 or toll free at 1 (866) 680-2906. You can also write to the Stanford IRB, Stanford University, Stanford, CA 94305-5401.

Please print a copy of this page for your records.

To participate in the study, click on the "Next >>" button below.

Protocol Director: Karin Forssell, Faculty Sponsor: Dr. Brigid Barron
Approval Period: 04/23/2009 - 12/31/2999

frequency

This school year, how often have you used an Internet resource to get teaching ideas?

- 3 Times a Week or more
- 1-2 Times a Week
- 1-2 Times a Month
- Less than Once a Month
- Never

Favorite online resource for teaching ideas:

On average, how often do you plan for a typical student to use a computer during your class? Approximately...

- 3 Times a Week or more
- 1-2 Times a Week
- 1-2 Times a Month
- Less than Once a Month
- Never

Please indicate whether you agree or disagree with the following statement:

"Digital resources such as classroom technology and Web-based programs help my students' academic achievement."

- Agree strongly
- Agree somewhat
- Disagree somewhat
- Disagree strongly

Any comments, questions, or clarifications?

THANK YOU!

References

AACTE Committee on Innovation and Technology (Ed.), (2008). *The Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators*. Routledge. 363 pages.

Andrews, D., Nonnecke, B., & Preece, J. (2003). Electronic Survey Methodology: A case study in reaching hard to involve Internet Users. *International Journal of Human-Computer Interaction. 16*(2), 185-210.

Angeli, C. (2005). Transforming a teacher education method course through technology: Effects on preservice Teachers' technology competency. *Computers & Education, 45*(4), 383–398.

Archambault, L., & Crippen, K. (2009). Examining TPACK among K-12 online distance educators in the United States *Contemporary Issues in Technology and Teacher Education, 9*(1). Retrieved from http://www.citejournal.org/vol9/iss1/general/article2.cfm

Bandura, A. (1977). Self-Efficacy: Toward a Unifying Theory of Behavioral Change. *Psychological Review, 84*(2), 191-215.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: Freeman.

Barnett, J., & Hodson, D. (2001). Pedagogical Context Knowledge: Toward a Fuller Understanding of What Good Science Teachers Know. *Science Teacher Education, 8*, 426-453.

Barron, B. (2004). Learning ecologies for technological fluency: Gender and experience differences. *Journal of Educational Computing Research, 31*, 1-36.

Barron, B. (2006) Interest and Self-Sustained Learning as Catalysts of Development: A Learning Ecology Perspective. *Human Development*, *49*, 193-224.

Barron, B., Martin, C. K., Takeuchi, L., & Fithian, R. (2009). Parents as learning partners in the development of technological fluency. *The International Journal of Learning and Media, 1,* 55-77.

Barron. B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecologies perspective. *Human Development, 49*, 193-224.

Bartlett, M. S. (1954). A note on the multiplying factors for various chi square approximations. *Journal of the Royal Statistical Society, 16* (Series B), 296-8.

Baruch, Y. & Holtom, B. C. (2008). Survey Response Rate Levels and Trends in Organizational Research. *Human Relations 61*(8),1139-1160.

Becker, H. J. (2000). Findings from the teaching, learning, and computing survey: Is Larry Cuban right? *Education Policy Analysis Archives, 8* (51). Retrieved on December 15, 2007 from http://epaa.asu.edu/epaa/v8n51.

Belden, N. (2002). *California teachers' perceptions of National Board Certification.* Santa Cruz, CA: Center for the Future of Teaching and Learning.

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society, Series B (Methodological) 57*(1), 125–133.

Bishop, G., Oldendick, R., & Tuchfarber, A. (1982). Effects of Presenting One Versus Two Sides of an Issue in Survey Questions. *The Public Opinion Quarterly 46*(1), 69-85.

Bosnjak, M., & Tuten, T. L.,(2001). Classifying response behaviors in Web-based surveys. *Journal of Computer-Mediated Communication, 6*(3). Retrieved from http://www.ascusc.org/jcmc/vol6/issue3/boznjak.html

Busch, T. (1995). Gender differences in self-efficacy and attitudes towards computers. *Journal of Educational Computing Research, 12*, 147-158.

California Department of Education (CDE, 2009) *Fact Book 2009: Handbook of Education Information*. CDE Press: Sacramento, CA. http://www.cde.ca.gov.

California Department of Education Educational Demographics Unit (2009). Certificated Staff for 2008-2009. Accessed online at http://dq.cde.ca.gov/dataquest/.

CEO Forum (2001). *Year 4 report: Key building blocks for student achievement in the 21st century.* Retrieved from http://www.ceoforum.org/downloads/report4.pdf.

Chen, M. (1986). Gender and computers: The beneficial effects of experience on attitudes. *Journal of Educational Computing Research, 2*, 265-282.

Chezem, J., Friesen, C., & Boettcher, J. (2003). Breastfeeding Knowledge, Breastfeeding Confidence, and Infant Feeding Plans: Effects on Actual Feeding Practices. *Journal of Obstetric, Gynecologic, & Neonatal Nursing, 32*(1), 40–47. DOI: 10.1177/0884217502239799.

Christensen, R. W. & Knezek, G. A. (2009) Construct Validity for the Teachers' Attitudes toward Computers Questionnaire. *Journal of Computing in Teacher Education, 25*(4), 143-155.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences – 2nd ed*. New Jersey: Lawrence Erlbaum Associates.

Cox, S. (2008). A conceptual analysis of technological pedagogical content knowledge. Doctoral Dissertation, Brigham Young University, Provo, UT.

Darling-Hammond, L. & Richardson, N. (2009). Teacher Learning: What Matters? *Educational Leadership, 66*(5), 47-63.

Darling-Hammond, L., Chung, R., & Frelow, F. (2002). Variation in teacher preparation: How well do different pathways prepare teachers to teach? *Journal of Teacher Education*, *53*(4), 286-302.

Davis, F.D., Bagozzi, R.P. & Warshaw, P.R., (1989). User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. *Management Science, 35*(8), 982-1003.

Ed-Data Partnership (2009). Fiscal, Demographic, and Performance Data on California's K-12 Schools. Accessed at http://www.ed-data.k12.ca.us/Navigation/fsTwoPanel.asp?bottom=%2Fprofile%2Easp%3Flevel%3D04%26reportNumber%3D16

Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *Educational Technology Research & Development, 53*(4), 25-39.

Fernchi, D. F. (2010). Female Child Education & Computer Technology. Downloaded September 29, 2010, from http://www.ehow.com/about_6638377_female-child-education-computer-technology.html

Forssell, K. S. (2009a, February). Roles and resources: Learning to teach with technology. Poster presented at the Student/Postdoc Conference for Science of Learning Centers (iSLC), Seattle, WA.

Forssell, K. S. (2009b, July). More roles and resources: Learning to teach with technology. Poster presented at the NSF site visit to the LIFE Science of Learning Center, Seattle, WA.

Forssell, K. S. (2010, May). Learning to Teach with One-to-One Technologies: Insights from the Analysis of Teachers' Learning Ecologies. In H. Spires (Chair), New Learning Ecologies Prompted by One-to-One Technology Programs. Symposium conducted at the annual meeting of the American Educational Research Association, Denver, CO.

Forssell, K. S. (2010, May). Supporting Teacher Technology Learning: Important Relationships in the Learning Ecology. Poster presented at the annual meeting of the American Educational Research Association, Denver, CO.

Frank, K., Zhao, Y., & Borman, K. (2004). Social Capital and the Diffusion of Innovations Within Organizations: The Case of Computer Technology in Schools. *Sociology of Education, 77*, 148-171.

Gandera, M. G. (2002). Staff development for school administrators: What is needed and wanted by new and veteran administrators. Thesis (Ed. D.), University of Southern California.

Goldhaber, D. & Hansen, M. (2009). National Board Certification and Teachers' Career Paths: Does NBPTS certification influence how long teachers remain in the profession and where they teach? *Education Finance and Policy 4*(3), 229-262.

Gossain, V. V., Bowman, K. A., & Rovner, D. R. (1993). The Actual and Self-Perceived Knowledge of Diabetes Among Staff Nurses. *The Diabetes Educator, 19*(3), 215-219, DOI:10.1177/014572179301900309

Gray, L., Thomas, N., & Lewis, L. (2010). *Teachers' Use of Educational Technology in U.S. Public Schools: 2009* (NCES 2010-040). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.

Hargittai, E. (2005). Survey Measures of Web-Oriented Digital Literacy. *Social Science Computer Review. 23*(3), 371-379.

Hargittai, E. (2010). Digital Na(t)ives? Variation in Internet Skills and Uses among Members of the ''Net Generation.'' *Sociological Inquiry, 80*(1), 92-113.

Harris, J., Grandgenett, N., & Hofer, M. (2010). Testing a TPACK-based technology integration assessment rubric. In C. D. Maddux, D. Gibson, & B. Dodge (Eds.), *Research highlights in technology and teacher education 2010* (pp. 323-331). Chesapeake, VA: Society for Information Technology & Teacher Education (SITE).

Harris, J., Mishra, P. & Koehler, M. (2009). Teachers' Technological Pedagogical Content Knowledge and Learning Activity Types: Curriculum-based Technology Integration Reframed. *Journal of Research on Technology in Education 41*(4), 393-416.

Hassani, S. N. (2006). Locating Digital Divides at Home, Work, and Everywhere Else. *Poetics 34*, 250-72.

Hatano, G. & Inagaki, K. (1986). Two courses of expertise. In H. Stevenson, H. Azuma, & K. Hakuta (Eds.), *Child development and education in Japan* (pp. 262–272). New York: Freeman.

Hennessy, S., Ruthven, K., & Brindley, S. (2005). Teacher perspectives on integrating ICT into subject teaching: Commitment, constraints, caution, and change. *Journal of Curriculum Studies, 37*(2), 155-192.

Hermans, R., Tondeur, J., Valcke, M., & van Braak, J. (2006, April). The impact of primary school teachers' educational beliefs on class use of computers. Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco, CA, USA.

Higgins, J. & Russell, M. (2003). *Teachers' beliefs about technology and instruction*. Boston, MA: Technology and Assessment Study Collaborative, Boston College.

Hill, H. C., Ball, D. L., & Schilling, S. G. (2008). Unpacking Pedagogical Content Knowledge: Conceptualizing and Measuring Teachers' Topic-Specific Knowledge of Students. *Journal for Research in Mathematics Education, 39*(4), 372-400.

Hill, H. C., Schilling, S. G., & Ball, D. L. (2004). Developing Measures of Teachers' Mathematics Knowledge for Teaching. *The Elementary School Journal, 105*(1), 11-30. DOI: 10.1086/428763

Hughes, J. (2005). The role of teacher knowledge and learning experiences in forming technology-integrated pedagogy. *Journal of Technology and Teacher Education, 13*(2), 277-302.

Imhof, M., Vollmeyer, R., & Beierlein, C. (2007). Computer use and the gender gap: The issue of access, use, motivation, and performance. *Computers in Human Behavior 23*, 2823-2837.

ISTE (2007). The ISTE NETS and Performance Indicators for Students (NETS•S). International Society for Technology in Education. Downloaded from http://www.iste.org/Libraries/PDFs/NETS_for_Student_2007_EN.sflb.ashx

Jenkins, H., Clinton K., Purushotma, R., Robinson, A. J., & Weigel, M. (2006). *Confronting the challenges of participatory culture: Media education for the 21st century.* Chicago, IL: MacArthur Foundation.

Kaiser, H. (1970). A second generation Little Jiffy. *Psychometrika*, *35*, 401-15.

Keigher, A. (2010). *Teacher Attrition and Mobility: Results From the 2008–09 Teacher Follow-up Survey* (NCES 2010-353). U.S. Department of Education. Washington, DC: National Center for Education Statistics. Retrieved March 30, 2011 from http://nces.ed.gov/pubsearch.

Kelly, M. (2010). Technological Pedagogical Content Knowledge (TPACK): A Content Analysis of 2006-2009 Print Journal Articles. In D. Gibson & B. Dodge (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2010* (pp. 3880-3888). Chesapeake, VA: AACE.

Khan, K. S., Awonuga, A. O., Dwarakanath, L. S., & Taylor, R. (2001). Assessments in evidence-based medicine workshops: loose connection between perception of knowledge and its objective assessment. *Medical Teacher, 23*(1), 92-94.

Koehler, M. J. & Mishra, P. (2008). Introducing Technological Pedagogical Knowledge. In AACTE (Eds.). *The Handbook of Technological Pedagogical Content Knowledge for Educators*. Routledge/Taylor & Francis Group for the American Association of Colleges of Teacher Education.

Krauskopf, K., Zahn, C., & Hesse, F. W. (2011). Leveraging the Affordances of YouTube: Pedagogical Knowledge and Mental Models of Technology Affordances as Predictors for Pre-Service Teachers' Planning for Technology Integration. *Proceedings of Society for Information Technology & Teacher Education International Conference 2011*.

Lawson, T. & Comber, C. (1999). Superhighways technology: Personnel factors leading to successful integration of information and communications technology in schools and colleges. *Journal of Information Technology for Teacher Education, 8*(1), 41-53.

Li, N. & Kirkup, G. (2007) Gender and cultural differences in Internet use: A study of China and the UK. *Computers & Education 48*, 301-317.

Lin, N. (2001). *Social Capital: A Theory of Social Structure and Action*. NY: Cambridge University Press.

Lin, N. (2004). Social Capital, in *Encyclopedia of Economic Sociology*, edited by Jens Beckert and Milan Zagiroski (2005), Routledge.

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. Lederman (Eds.) *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 95-132). Dordrecht: Kluwer Academic Publishers.

Manfreda, K. L., Bosnjak, M., Berzelak, J., Haas, I., & Vehovar, V. (2008). Web surveys versus other survey modes: A meta-analysis comparing response rates. *International Journal of Market Research, 50*(1), 79-104.

Margolis, J. (2008). *Stuck in the Shallow End: Education, Race, and Computing*. Cambridge, MA: MIT press.

Markow, D. & Cooper, M. (2008). *The MetLife survey of the American teacher: Past, present, and future*. Retrieved from http://www.metlife.com/assets/cao/contributions/citizenship/teacher-survey-25th-anniv-2008.pdf.

Marsden, P. V. (2002). Egocentric and sociocentric measures of network centrality. *Social Networks 24*, 407-422.

Mercier, E.M., Forssell, K.S. & Barron, B.J. (2008, March). Documenting engagement in technologically mediated production activity across settings and time: the role of prior interests in sustaining activity. Presented at the annual meeting of the American Educational Research Association, New York, NY.

Meskill, C., Mossop, J., DiAngelo, S., & Pasquale, R.K. (2002). Expert And Novice Teachers Talking Technology: Precepts, Concepts, And Misconcepts. *Language Learning & Technology 6*(3), 46-57.

Mishra, P. & Koehler, M.J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record, 108*(6), 1017-1054.

Mishra, P. & Koehler, M.J. (2007). Technological Pedagogical Content Knowledge (TPCK): Confronting the Wicked Problems of Teaching with Technology. Invited address at the annual meeting of Society Information Technology and Teacher Education. Retrieved October 2nd, 2007, from http://www.aace.org/conf/site/ mishra_invited.doc

National Board for Professional Teaching Standards (2007). Making a Difference In Quality Teaching and Student Achievement. Downloaded from http://www.nbpts.org/index.cfm?t=downloader.cfm&id=693.

National Research Council. (1999). *Being fluent with information technology*. Washington, D.C.: National Academies Press.

NEA Research (2010). *Rankings & Estimates: Rankings of the States 2009 and Estimates of School Statistics 2010*. Downloaded from http://www.nea.org/assets/docs/010rankings.pdf .

Niess, M. (2008). Mathematics Teachers Developing Technology, Pedagogy and Content Knowledge (TPACK). In K. McFerrin et al. (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2008* (pp. 5297-5304). Chesapeake, VA: AACE.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge, *Teaching and Teacher Education, 21*, 509-523.

Niess, M. L. (2006). Guest Editorial: Preparing teachers to teach mathematics with technology. *Contemporary Issues in Technology and Teacher* Education [Online serial]*,* *6*(2). Downloaded from http://www.citejournal.org/vol6/iss2/mathematics/article1.cfm

Pallant, J. (2010). *SPSS Survival Manual: A step by step guide to data analysis using SPSS. 4th Edition*. New York: McGraw Hill.

Partnership for 21st Century Skills, (n.d.). Viewed online at http://www.p21.org/index.php?option=com_content&task=view&id=254&Itemid=120.

PBS and Grunwald Associates, LLC (2010). Digitally Inclined. Downloaded from http://www.pbs.org/teachers/_files/pdf/annual-pbs-survey-report.pdf

Penuel, W.R., Riel, M., Krause, A.E. & Frank, K. A. (2009). Analyzing Teachers' Professional Interactions in a School as Social Capital: A Social Network Approach. *Teachers College Record 111*(1), 124-163.

Player-Koro, C. (2007, August). Why teachers make use of ICT in education. Paper presented at the 10th Pre-Conference of Junior Researchers of EARLI, Budapest, Hungary.

Presser, S. & Schuman, H. (1980) The Measurement of a Middle Position in Attitude Surveys. *Public Opinion Quarterly*, downloaded November 14, 1009 from http://www.amstat.org/sections/SRMS/Proceedings/papers/1978_008.pdf

Raju, P. S., Lonial, S. C., & Mangold, W. G. (1995). Differential effects of subjective knowledge, objective knowledge, and usage experience on decision making: An exploratory investigation. *Journal of Consumer Psychology 4*(2), 153-180.

Rand California (2009). Teacher Demographics Statistics. Downloaded 5/19/10 from http://ca.rand.org/cgi-bin/prcert1/prcert.cgi

Reeve, R. (2008). Technological Pedagogical Content Knowledge and the Context: An Integrated Model. In K. McFerrin et al. (Eds.), *Proceedings of Society for*

Information Technology & Teacher Education International Conference 2008 (pp. 5310-5312). Chesapeake, VA: AACE.

Ruble, T. L. & Stout, D. E. (1990). Reliability, Construct Validity, and Response-Set Bias of the Revised Learning-Style Inventory (LSI-1985). *Educational and Psychological Measurement 50*, 619-629.

Russell, M., Bebell, D., O'Dwyer, L., & O'Connor, K. (2003). Examining teacher technology use: Implications for preservice and inservice teacher preparation. *Journal of Teacher Education, 54*(4), 297-310.

Ryymin, E., Palonen, T., & Hakkarainen, K. (2008). Networking relations of using ICT within a teacher community, *Computers & Education, 51*(3), 1264-1282.

Sax, L. J., Gilmartin, S.K., & Bryant, A.N. (2003). Assessing Response Rates And Nonresponse Bias in Web and Paper Surveys. *Research in Higher Education, 44*(4), 409-432.

Schmidt, D., Baran, E., Thompson, A., Koehler, M., Mishra, P. & Shin, T. (2009). Examining Preservice Teachers' Development of Technological Pedagogical Content Knowledge in an Introductory Instructional Technology Course. In C. Crawford et al. (Eds.), *Proceedings of Society for Information Technology and Teacher Education International Conference 2009* (pp. 4145-4151). Chesapeake, VA: AACE. Retrieved from http://www.editlib.org/p/31308.

Scholastic and the Bill & Melinda Gates Foundation (2010). *Primary Sources: America's Teachers On America's Schools*. Scholastic Inc. U.S.A.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Snoeyink, R. & Ertmer, P. A. (2001/2). Thrust into technology: How veteran teachers respond. *Journal of Educational Technology Systems, 30*(1), 85-111.

U.S. Department of Education, Office of Educational Technology, *Transforming American Education: Learning Powered by Technology*, Washington, D.C., 2010.

U.S. Department of Labor (2009). *Labor Force Characteristics by Race and Ethnicity, 2009.* U.S. Bureau of Labor Statistics Report 1026. Downloaded from http://www.bls.gov/cps/cpsrace2009.pdf.

US Bureau of Labor Statistics (2009) Downloaded from ftp://ftp.bls.gov/pub/special.requests/lf/aat11.txt.

Vekiri, J. & Chronaki, A. (2008). Gender issues in technology use: Perceived social support, computer self-efficacy and value beliefs, and computer use beyond school. *Computers & Education 51*, 1392-1404.

Warschauer, M. & Matuchniak, T. (2010). New technology and digital worlds: Analyzing evidence of equity in access, use, and outcomes. *Review of Research in Education, 34*(1), 179-225.

Williams, D., Coles, L., Wilson, K., Richardson, A., & Tuson, J. (2000). Teachers and ICT: Current use and future needs. *British Journal of Educational Technology, 31*(4), 307-320.

Windschitl, M. & Sahl, K. (2002). Tracing Teachers' Use of Technology in a Laptop Computer School: The Interplay of Teacher Beliefs, Social Dynamics, and Institutional Culture. *American Educational Research Journal, 39*(1), 165-205.

Zhao, Y. & Cziko, G. A. (2001). Teacher adoption of technology: A perceptual control theory perspective. *Journal of Technology and Teacher Education, 9*(1), 5-30.

Zhao, Y. & Frank, K. A. (2003). Factors Affecting Technology Uses in Schools: An Ecological Perspective. *American Educational Research Journal, 40*(4), 807-840.

Zhao, Y., Pugh, K., Sheldon, S., & Byers, J. L. (2002). Conditions for classroom technology innovations. *Teachers College Record, 104*(3), 482-515.

Zimmerman, B. J. (2000). Self-Efficacy: An Essential Motive to Learn. *Contemporary Educational Psychology 25*, 82-91.