ABSTRACT

HERVEY, LISA GERALYN. Between the Notion and the Act: Veteran Teachers' TPACK and Practice in 1:1 Settings. (Under the direction of Dr. Hiller A. Spires).

The technological pedagogical content knowledge (TPACK) framework is a nuanced lens to study teachers' 21st century professional knowledge and practice (Mishra & Koehler, 2006). Veteran teachers in 1:1 settings have not been the focus in TPACK research. In this mixed-methods study, veteran teachers were surveyed to determine their self-reported technological pedagogical content knowledge (TPACK). Qualitative data included teachers' videotaped lessons, interview transcripts and field notes. Discussion highlights the need for a valid and reliable instrument to measure secondary teachers' TPACK, the value of *a priori* coding to illuminate TPACK, and generational challenges veteran teachers face while practicing in 1:1 settings.

Between the Notion and the Act: Veteran Teachers' TPACK and Practice in 1:1 Settings

by
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DEDICATION

To my husband, George E. R. Hervey – with your love, support, and patience – all is possible.

BIOGRAPHY

I was born into a NAVY family and spent my K-12 years moving from California to Tennessee to Nevada to Virginia to Pennsylvania with my Mom and Dad. After high school graduation in 1987, I spent seven years talking to F-14, SR-117, A-6 and P-3 pilots as an air traffic controller in the NAVY. After an honorable discharge in 1994, I pursued a B.S. in K–12 Special Education and K–6 Elementary Education at Central Michigan University. I taught middle grades language arts at a public separate school in Raleigh, North Carolina from 1998 to 2008. I qualified for my National Board for Professional Teaching Standards certification in 2003. In 2007, I earned my M.Ed. in K–12 Reading from North Carolina State University. I started my doctoral program in the department of Curriculum and Instruction at NC State in Fall of 2008.

I was a research assistant, under the direction of Dr. Hiller Spires, for the first two and half years of my doctoral program. I worked on a NSF funded project entitled *Narrative Theatre*. *Narrative Theatre* provided an appealing and dynamic narrative-centered online learning environment that scaffolds 6th graders in crafting more sophisticated narrative writing products. I helped to conduct, analyze and report the impacts that *Narrative Theatre* had on students' writing self-efficacy and achievement. In December of 2010, I was hired as a research associate to co-lead work on a project funded by the U.S. Department of Education, conducted in partnership with Consortium for School Networking (CoSN) and State Education Technology Directors Association (SETDA). This DOE project focuses on the research and development of online communities of practice for educators and related professions. I also develop and facilitate online professional development co-sponsored by the Friday Institute's 1:1 Collaborative and Learn NC for in-service teachers across North Carolina: *Innovate to Transform the Classroom with Web 2.0 Tools*, *English I and Web 2.0 Tools in 1:1 Technology Settings and 9th - 12th Grade Social Studies Instruction in 1:1 Settings*. I regularly teach the summer online offering of *Content Area Reading*, a graduate course in NC State's Department of Curriculum, Instruction and Counselor Education.

I met the love of my life in 1998. I started dating him in 2001. We married in 2007. We do not have children. We have cats. Running keeps me sane.

I subscribe to a pragmatic worldview. I am searching for the *truths* for the "what" and the "how" that lead to practical solutions for helping experienced teachers' increase their professional knowledge for technology in the reality of the K-12 classroom. I am a "digital immigrant" and have experienced the "wicked" problems associated with technology in my own instructional practices. So on one hand, I have great empathy for teachers as they attempt to integrate technology during instruction. It is not easy. At times, the learning curve can be very treacherous. On the other hand, I was able to negotiate that learning curve and now understand that as intimidating as technology can be, it can be learned. It can and should be leveraged in endless ways to support and enhance students' learning. I believe teachers are obligated to create and implement effective technology infused lessons to prepare their students for the future that they deserve.

ACKNOWLEDGEMENTS

I would like to thank my advisor Dr. Hiller A. Spires who has been my champion since beginning this journey. I have learned so much from you in the last three years. You have always encouraged me and pushed me to do my best. Thank you for the time, patience and advice you have graciously given me.

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I would like to thank my colleagues at the Friday Institute at North Carolina State University. You all have supported and encouraged me ever since I started working there in 2008. I will forever be grateful for the opportunities I have been given by studying and working at this institution.

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I would like to thank my family and friends, who without complaint have tolerated me over the last three years. To my husband, George, I thank you for staying married to me. To my Mom, Dad, Sara, Catherine, and Emilee, I thank you for loving me. To my mother-in-law, Karolyn, I thank you for always grounding me when my world was spinning. To my friend Danielle, I thank you for your warm hugs of support. To my friend, Dora, I thank you for all the phone calls and notes filled with encouragement and love.

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CHAPTER ONE: INTRODUCTION

The exponential availability of technology in today's classroom requires K-12 educators to redefine and repurpose their instructional practices (National Center for Educational Statistics, 2008, U.S. Department of Education, 2010). According to Koehler and Mishra (2008), effective 21st century teachers must demonstrate an in-depth understanding of the complex relationships between technology, content and pedagogy during instruction. Realizing that successfully integrating technology is no small feat, Mishra and Koehler (2006) provocatively refer to teaching with technology as a "wicked problem" to emphasize the novel and dynamic nature of this phenomenon.

Context of the Problem

Experienced teachers' professional knowledge, once developed, remains stable (Gess-Newsome, 1999). Efficaciously weaving a new knowledge domain, such as technology knowledge, into their pre-existing professional knowledge has been a daunting task for veteran teachers (Bebell & Kay, 2010; Hughes, 2005; Hughes & Schraber, 2008). Veteran teachers have to do more than just learn about current educational technology. Veteran teachers must develop specific capacities that continually evolve with each new advance of technological innovation.

Currently, over 37% of U.S. public school districts have launched 1:1 technology learning initiatives (National School Board Association, 2010). These initiatives provide teachers and students with internet-connected wireless computing devices for use in the classroom and are commonly referred to as "1:1 settings." The surge in 1:1 computing initiatives in K-12 education further adds to the complexity veteran teachers face in a 21st

century educational landscape. Constant access to technology and information in 1:1 settings creates a "new learning ecology" in which teachers must make a "pedagogical shift to accommodate learning that is continuous, changing, and above all exponential" (Spires, Wiebe, Young, Hollebrands, & Lee, 2009, p. 10). The term "1:1 settings" delineates how technology is available to students and teachers in the classroom; it reveals nothing about what is required to effectively teach in these environments.

Theoretical Framework

How technological resources, when leveraged during instruction, promote both student engagement (Sandholtz, Ringstaff, & Dwyer, 1997) and student achievement (Kulik, 2003; Sivin-Kachala & Bialo, 2000) is well documented. Recent scholarly discourse has considered how Shulman's (1986) pedagogical content knowledge (PCK) framework should be expanded to include the teachers' knowledge now required to effectively support student learning with technology. Figure 1.1 illustrates the components and conceptual structure of Shulman's PCK framework.

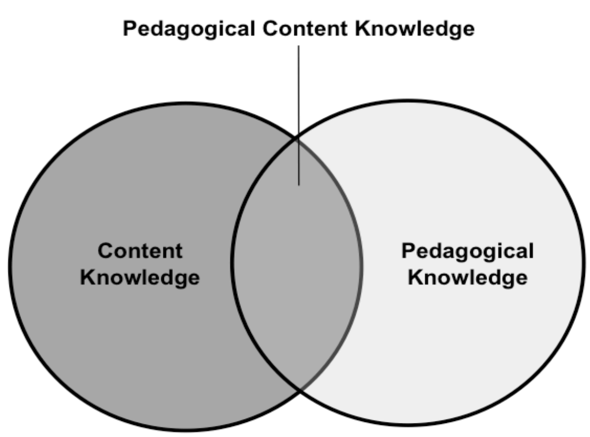

Figure 1.1. Pedagogical content knowledge framework. Adapted from "Those who understand: Knowledge growth in teaching," by L. Shulman, 1986, *Educational Teacher 15*(2), p. 4-14. Copyright by the 1986 American Educational Research Association.

Shulman asserted that teachers' general pedagogical knowledge and knowledge about content exist independently. The overlap of these two knowledge domains is PCK. Gess-Newsome (1999) identified aspects of the PCK framework that have effectively contributed to the study of teaching. The PCK framework has:

- provided a new analytical frame for organizing and collecting data on teacher cognition;
- highlighted the importance of subject matter knowledge and its transformation for teaching;
- incorporated findings across related constructs; and
- provided for a more integrated vision of teacher knowledge and classroom practice (p.10, bullets added).

The PCK framework has proven to be a valuable lens to examine both teachers' possession of professional knowledge and how that professional knowledge informs their instructional practice.

Building on the intent of Shulman's work, Mishra and Koehler (2006) developed a 21st century transformation of the PCK framework. In their framework, as shown in Figure 1.2, adding teachers' technology knowledge to teachers' existing PCK, created three new constructs: (a) technological content knowledge (TCK), (b) technological pedagogical knowledge (TPK), and (c) technological pedagogical content knowledge (TPACK).

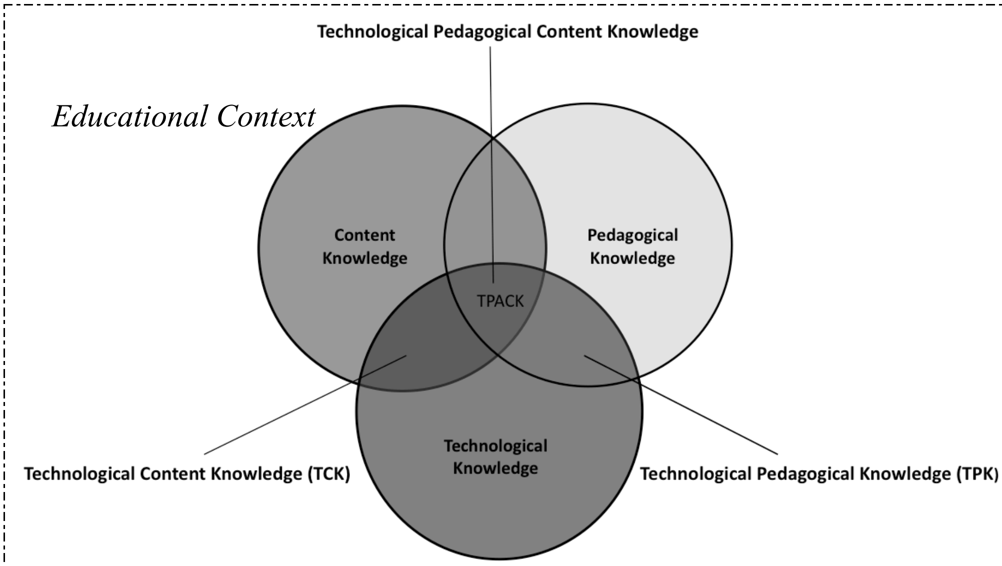

Figure 1.2. Technological pedagogical content knowledge framework. Adapted from "Technological pedagogical content knowledge: A framework for teacher knowledge," by P. Mishra and M. J. Koehler, 2006, *Teachers College Record, 108*(6), p. 1017-1054. Copyright by the Teachers College, Columbia University.

A foundational underpinning of the TPACK framework is that teachers must balance their technology, pedagogy, and content knowledge during classroom instruction to effectively further student learning (Koehler & Mishra, 2008). So then, how does the TPACK framework offer a nuanced lens on teacher professional knowledge and practice in relation to educational technology? First, it delineates how teachers' developing technology knowledge interacts with teachers' *current, established* PCK, emphasizing how teaching with technology is fluid and complex. Teachers generally have a deep *knowledge of their content* as well as the *knowledge of how* to teach it. What do teachers need to know when technology enters the equation? Teachers must develop both knowledge associated with, but not limited to, content related specialized software and tools (i.e., TCK) as well as form a new pedagogical knowledge of how to teach with the technology (i.e., TPK). The TPACK framework offers a structure to study TCK and TPK, respectively. Second, the TPACK framework illustrates that teachers design their instructional practices using their content, technology, and pedagogy knowledge (i.e., TPACK) domains in an integrated manner based on their *present* educational environment. Clearly a 1:1 setting will influence how teachers enact their curriculum. Compare this to teachers who only have access to a computer lab for one class period a few times per month. 1:1 contexts call for radically different pedagogical choices; thus a radically different form of TPACK.

The TPACK framework aids researchers in fully understanding teachers' content, technology, and pedagogy knowledge. The framework can assist in the deconstruction of instructional practices in ubiquitous computing settings. The TPACK framework better contextualizes the milieu that has become the art and science of teaching in the 21st century.

The Research Problem

Much of the early research only used survey studies to identify variables that may have influence over in-service teachers' use of technology in the classroom (Becker & Ravitz, 1999). Specifically, these studies used self-report methodologies to capture teachers' computer skills, frequency of their technology use in the classroom and what technologies were available to them (Anderson & Ronnkvist, 1999; Puma, Chaplin & Pape, 2000; Smerdon et al., 2000). Although valuable in their own right, these studies ignored the complex and messy process veteran teachers navigate as they develop professional knowledge for effective technology integration (Lim & Chai, 2008; Windschitl & Sahl, 2002). When integrating technology to transform their instructional practices, veteran teachers must make substantial additions and adaptations to their professional knowledge base, not just their *technology use*.

To my knowledge, after conducting extensive research, veteran teachers have not been the target population for current TPACK research. Specifically, findings from valid and reliable measures of secondary veteran teachers' TPACK knowledge and observations of their practice in 1:1 classrooms have not been made available in the literature. How experienced teachers integrate technology during their instructional practice is tactical, strategic, and epistemological: the integration of technology results from the kinds of TCK, TPK, and TPACK they possess. I believe it necessary to research secondary veteran teachers' TPACK and their practices in 1:1 settings.

Purpose and Research Questions for the Study

The aim of my study was to identify secondary veteran teacher's possession of TCK, TPK, and TPACK and how these knowledge domains are reflected in their instructional practices in 1:1 settings. I have used a sequential explanatory mixed methods design (Creswell & Plano, 2007) to collect quantitative and qualitative data from secondary veteran teachers practicing in 1:1 settings. In the first quantitative phase, I collected data using an adapted *Survey of Teachers' Knowledge of Teaching and Technology* from 81 veteran secondary teachers participating in the North Carolina Learning Technology Initiative (NCLTI). The NCLTI facilitates North Carolina school districts transition to 1:1 settings. In the connecting phase of the study, I conducted statistical analysis on the data collected to inform my purposeful selection of six participants as case studies (two teachers per case). In the second qualitative phase, I videotaped teachers' lessons, conducted stimulated recall and semi-structured interviews and took field notes to analyze instructional practices among the TCK, TPK, and TPACK cases. The research questions were:

1. How do revisions made to the *Survey of Teachers' Knowledge of Teaching and Technology* impact its reliability and validity for use with secondary teachers?
2. What are the self-reported levels of secondary veteran teachers' technological pedagogical content knowledge (TCK, TPK, and TPACK) practicing in 1:1 settings?
3. How are veteran teachers' technological pedagogical content knowledge (TCK, TPK, and TPACK) reflected in their instructional practices implemented in 1:1 settings?

Significance and Limitations

As we move further into the 21st century, there is little doubt that veteran teachers' instructional practices will undergo a metamorphosis. We also know that the 1:1 setting will become commonplace in public education. To better support these shifts, educational stakeholders need to know how TCK, TPK, and TPACK impact veteran teachers' execution of instructional practices in 1:1 settings. This study provided several means to that end. First, this study attempts to bridge two bodies of research on 1:1 and TPACK that has commonly been studied separately. Second, the revised TPACK survey had potential to provide more robust construct validity and reliability for use with secondary teachers. Third, direct measures of veteran teachers' TPACK and actual practice in 1:1 classrooms added significantly to under-theorized aspects of the TPACK framework. Finally, this study captured a collection of new understandings about both the supportive conditions and struggles veteran teachers' need and face as they fully develop their TPACK in 1:1 settings.

This study had several limitations. First, mixed methods exploratory sequential research design can only provide descriptive explanations about the relationship among quantitative and qualitative data results. That is, in the absence of controlled conditions, conclusions about cause-and-effect relationships between veteran teachers' TPACK and performance could not be drawn. Second, the sample size was very small for this study and negatively impacted some planned statistical analyses. Third, this study only involved veteran teachers practicing in 1:1 settings and may not be representative or generalized to the entire teacher population. Fourth, bias and issues of "bracketing" may have influenced data collection and analysis. Specifically, in the qualitative phase of the study, I found it difficult to remain non-judgmental during data collection with participants since I was already aware of their self-perceived TCK, TPK, and TPACK. However, I have made make every effort to present adequate evidence, from the data, to support this study's findings.

CHAPTER TWO: REVIEW OF THE LITERATURE

The aim of this study was to better understand veteran teachers' professional knowledge and instructional practice in 1:1 settings. Teaching is an introspective profession. As such, researchers have an extraordinary curiosity about features of teachers' professional knowledge development and the instructional practices that are guided by that knowledge. Today, the key domains in Mishra and Koehler's (2006) technological pedagogical content knowledge (TPACK) framework are "hot topics" in the world of education research. Fully understanding constructs in a 21st century teachers' professional knowledge such as technological content knowledge (TCK), technological pedagogical knowledge (TPK) and technological pedagogical content knowledge (TPACK) is an emerging and meticulous undertaking across all educational contexts.

The purpose of this review was to examine research in seven related key areas: (a) a new educational era (b) experienced teacher pedagogy in a new educational era, (c) research leading to the development of the TPACK framework, (d) the TPACK theoretical framework, (e) current application of the TPACK framework in the literature, (f) the TPACK framework and 1:1 computing settings, and (g) issues of reliability and validity for the current TPACK survey.

A New Era in Education

K-12 education has entered a new era. The National Center for Educational Statistics (2008) reported "instructional rooms with access to the Internet and other technologies increased from 51% in 1998 to 94% in 2005." In ever increasingly dynamic educational settings, technological resources must be thoughtfully integrated into the curriculum to promote student engagement as well as achievement. As such, K–12 teachers need to have the appropriate knowledge and experience to take full advantage of the potential technology offers for enhanced student learning. Only one-third of public school teachers felt "well prepared" or "very well prepared" to integrate technology into their practice (National Center for Educational Statistics, 2001). Education leaders and policy makers urge K-12 teachers to continually innovate their practice with technology; however, many teachers still struggle with how to make *innovative practices* a reality in their *21st century classrooms*. Brief overviews of these new "innovative practices" and "21st century classrooms" are presented in the following sections: (a) technology integration and (b) 1:1 settings.

Technology Integration

There is ample evidence that technology integration can have a significant impact on teaching and learning (Ferdig, 2006; Russell, Bebell, O'Dwyer & O'Connor, 2003; Ertmer, Gopalakrishman & Ross, 2001). Specifically, technology integration can potentially improve teacher-student relationships (McGrath, 1998), encourage project-based learning (Park & Ertmer, 2007; ChanLin, 2008), and support the acquisition of higher order thinking and problem solving skills (Barron, Kemker, Harmes & Kalaydjian, 2003). These studies provide substantive evidence that technology integration has the potential to improve student achievement in content area learning as well as positively shift teacher-student relationships.

To provide the reader a better contextual understanding for the remainder of this literature review, several variations in the definitions of technology integration are discussed. For instance, technology integration can be simply articulated as *the use of existing tools, including hardware, software, and the Internet in the classroom.* However, in light of ever emerging innovative technologies, a more transformative definition may be more appropriate. Harris (2008) claims that technology integration involves "the pervasive and productive use of educational technologies for purposes of curriculum-based learning and teaching" (p. 252). Technology integration, therefore, is a teachers' sustained use of technology in all phases of a lesson.

1:1 Settings

In 2006, Hayes surveyed 2,500 school systems with at least 4,000 students. She found that 23% of school systems were implementing 1:1 computer programs in at least one grade. 48% of the school district technology officers surveyed reported that a 1:1 program would be implemented in their schools by 2011(2006). The National School Board Association conducted a survey of all U.S. public school districts and found that 37% have launched 1:1 technology learning initiatives (2010). Taken together, these findings suggest that 1:1 computing initiatives are steadily increasing across the nation.

Penuel (2006) completed a synthesis of studies that employed comparison group designs for 1:1 laptop projects in K-12 environments. According to his findings, teachers must adjust their practice to take full advantage technologies associated with 1:1 settings. Garthwait and Weller (2005) found that the presence of ubiquitous computing, alone, did "not automatically shift instructional styles from teacher-centered to student-centered" (p. 373). Teachers practicing in 1:1 settings must develop nuanced and dynamic professional knowledge to make instructional choices that are student–centered.

Experienced Teacher Pedagogy in a New Education Era

Experienced teaching is a complex phenomenon. Veteran teachers impart their experiences, knowledge and goals into their practice. They make sense of their content, call upon professional knowledge and take action. Shulman (1986) conceptualized teachers' best thinking during instruction as *pedagogical content knowledge* (PCK).

Since the 1980s, Shulman's PCK framework has had an historic impact in the education field. Shulman (1986) defined PCK as "that amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (p. 8). According to Shulman, teachers' enactment of their PCK during instruction is as follows:

> It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners and presented for instruction. (p. 8)

Teachers need to master two types of content knowledge: (a) deep knowledge of the subject itself and (b) knowledge of appropriate curricular scope and sequence. Teachers' pedagogical knowledge is concerned with choosing the most useful forms of representing and communicating content combined with their knowledge of how students best learn the specific concepts and topics of a subject (i.e., scope and sequence).

Applefield, Huber, and Moallem's (2001) study found that teachers' pedagogical understandings have considerable influence on their decisions regarding lessons using technology. Veteran teachers' professional knowledge takes root over time as they develop ideas about what it takes to be an effective teacher and how students best learn. Therefore, teachers who were taught in a traditional manner may hold on to traditional pedagogical practices when attempting to integrate technology. In fact, Webb and Cox's (2004) review on computer-related pedagogy suggested that most in-service teachers fail to explore many of the affordances of computers and technology to create more engaging and constructivist-oriented pedagogy. These teachers either may not see the affordances of technology or may take up only the affordances that are consistent with their pre-existing professional knowledge. More often than not, teachers just attach new approaches on top of existing practices without really altering instruction to effectively integrate technology. Experienced teachers' efforts to integrate technology into their school curricula are often limited by barriers fundamentally rooted in their professional knowledge about teaching and learning (Wang, Ertmer & Newby, 2004). Thus, innovation is less likely to be adopted by experienced (e.g., veteran) teachers if it deviates greatly from their knowledge base.

Veteran teachers need to understand educational technology applications deeply and flexibly so they can better help students meet curricular driven learning outcomes alongside tacit 21st century skills such as collaboration, play, and problem-solving (Pink, 2006). Ultimately, these teachers need to see how technology can create connections between content area learning and their students' everyday lives. In a three-year longitudinal study by Levin and Wadmany (2006), teachers' views on learning, teaching, teaching models, and technology were defined, indentified and categorized to provide dimensions for comparison and change over time. In general, the teachers' pedagogical practices did shift, taking on a more "transformative orientation or multiple dimensional view toward teaching, learning and technology" (p.161). This study highlights the importance of both the directionality and evolution of experienced teachers' beliefs with regard to technology integration.

Research Leading to the Development of the TPACK Theoretical Framework

To position my study in the context of previous and related research, selected studies, precursors to the development of the TPACK theoretical framework, are described and discussed in the next section.

Pierson (2001) attempted to discover if in-service teachers' pedagogical expertise transferred to exemplary use of technology during instruction. She was the first researcher to propose adding *technology knowledge* to Shulman's PCK framework. Pierson's work is significant. Her findings clearly illustrated a need for an operational definition of "technology integration." For example, she found when creating her participant pool that some teachers who were described by their peers as "exemplary technology users" (p.416) had limited skills in integrating technology. Pierson had each of the teachers in her study provide definitions for technology integration. Her work anchors initial conceptualizations of a new pedagogical construct related to teachers' use of technology. Pierson is one of the original architects of TPACK.

In 2003, Mouza attempted to identify effective ways to improve teachers' technological skills and technological pedagogy. Her case studies revealed that professional development for technology integration did help teachers become "aware" of new pedagogical strategies associated with the use of technology. Overall, however, the teachers in the study continued to use their existing pedagogical beliefs throughout the implementation of learning activities with technology. This study underscored the ongoing struggle between the actualization of technology innovation in classrooms and the development of teachers' pedagogies associated with technology. Much later, Koehler, Mishra, & Yahya (2007) clarified Mouza's findings as an "appreciation of the complex set of interrelationships between users, tools and instructional practices" (p. 742). Teachers must adjust pedagogical beliefs to effectively integrate their technology, pedagogy and content knowledge.

In 2005, Niess, in an effort to describe the nature and difficulties associated with teachers' development of professional knowledge for technology use, found that some graduate level math and science student teachers who were participating in a 1-year program focusing on the integration of technology, failed to meet technology related pedagogical development outcomes. These results had implications for future research questions: What program models support teachers' professional knowledge development for effective technology integration? What are the important required teacher skills and professional knowledge for effectively using technology? This research challenged researchers to uncover the specific demands associated with effectively preparing teachers for the unique instructional demands of the 21st century.

In the same year, Hughes (2005) identified a potential set of aspects found in in-service teachers' prior knowledge, learning experiences, and current technology practice that may be indicative of more transformative approaches to technology integration in their classrooms. Specifically, her case study research revealed that professional development aimed at improving teachers' professional knowledge for effective technology use should: (a) focus on supporting teachers in sharing their knowledge and questions, (b) connect learning to contexts of teaching (i.e., subject-specific); and (c) promote active engagement with other teachers. This research helped to further conceptualize how educators' thoughts and experiences are directly linked to how they carry out technology integration in their classroom. Helping teachers become transformative around technology use in their classroom requires a closer examination of what actually informs, develops, and propels their professional knowledge when leveraging technology during instructional practice.

In 2006, Ferdig's research review added significantly to the narrative for the body of research involving technology, the innovation process, and teachers. From research and publications, he fleshed three domains for learning and teaching with technology: pedagogy, people, and performance. Ferdig suggested that an evaluative model or framework is required not only for "assessing teachers' pedagogy for technology, but also as a means to examine performance outcomes for both curriculum goals and appropriateness of tool application" (p. 757). Ferdig's work helped to provide a more cohesive roadmap as researchers continued to broaden the research scope of educational technology.

In 2006, in response to these as well as similar research studies, Mishra and Koehler posited their new theoretical framework of teachers' professional knowledge; depicting it as technological pedagogical content knowledge (TPACK).

The TPACK Theoretical Framework

The TPACK theoretical framework adds teachers' technology knowledge to Shulman's PCK framework (see Figure 1.2). Koehler and Mishra (2008) asserted that teaching with technology requires TPACK, or an ability to dynamically blend content, pedagogy and technology flexibly during the act of teaching. The multifaceted nature of the

TPACK framework suggest that teachers' developing pedagogies may only be fully developed in a integrated manner, and not as separate knowledge bases.

Mishra and Koehler (2006) created three new constructs (e.g., TCK, TPK, and TPACK) when they added technology knowledge to Shulman's PCK. According to Mishra and Koehler (2006) TPACK is enacted using "components of the framework in pairs: pedagogical content knowledge (PCK), technological content knowledge (TCK) and technological pedagogical knowledge (TPK)" (p. 1026). Mishra and Koehler (2006) offered following definitions and assumptions about these triads:

- PCK considers the illustration and formulation of concepts to be taught and learned. The pedagogical techniques required include an understanding of what makes concepts easy or difficult to learn and combining that with an understanding of students' prior knowledge. Moreover, an educator must identify instructional strategies best suited to accomplish conceptual representation while simultaneously addressing learners' misunderstandings and difficulties.
- TCK represents the reciprocal relationship between technology and content. Ever emerging technologies make it possible to accommodate ways to navigate content. Educators need to know the ways technology can represent concepts in their content area to help improve their students' understanding of the content.
- TPK primarily entails a deep knowledge of the existence, components and capabilities of various technologies for use in teaching and learning settings, as well as understanding how students' learning might change as a result of using a specific

> technology. Instructors should be familiar with a variety of tools that are appropriate for general pedagogical tasks; able to choose tools that are well-suited to the task.

Cox's (2008) dissertation work focused on clarifying only the TCK, TPK, and TPACK constructs. She explained:

> Each of the main areas—technological knowledge, pedagogical knowledge, and content knowledge—is extremely broad and I did not believe that they needed to be treated in depth in the conceptual analysis. Pedagogical content knowledge plays a major role in TPACK, but I decided not to include this construct in the conceptual analysis as others have already done that work (p. 32).

She used a conceptual analysis to identify the essential features of and relationships between TCK, TPK, and TPACK to further develop and expand their definitions. She suggested that:

- The necessary attributes of TCK are the use of appropriate technology in a particular content area to investigate, represent, or transform that content and/or the selection or transformation of technology based on the imperatives of a particular content (p. 41).
- TPK includes the use of appropriate technology as part of a pedagogical strategy considering the interaction of the technology and pedagogy, and student learning (p. 43).
- TPACK blends the use of appropriate technology in a particular content area as part of a pedagogical strategy within a given educational context to develop students' knowledge of a particular topic or meet an educational objective or student need (p. 45).

Thus, TPACK includes all three knowledge areas of content, pedagogy and technology, and when in concert with the use of content-specific strategies, sets it apart from TPK, which employs general pedagogical strategies, and TCK, which is independent of pedagogy.

To further aid the reader, conceptual differences between TCK, TPK, and TPACK are further presented and discussed in the next section.

Conceptual Distinctions for TCK, TPK, and TPACK

A review of the literature revealed additional and valuable granulations of TCK, TPK, and TPACK where researchers differentiate between them conceptually. First, TCK conceptualizes teachers' understanding of how the application of technology can directly support student skill development in a given discipline; teachers firmly grasp the reciprocal relationship between a selected technology and their students' content learning (Mishra & Koehler, 2006). That is, teachers must be intimately familiar with their content, as well as have the capacity to effectively choose and appropriately leverage technology to support their students' learning and achievement. Therefore, TCK could be described as *using technologies best suited for addressing content learning.* Every technology choice made by teachers "affords and constrains the types of content ideas that can be taught" (Koehler & Mishra, 2008, p. 16). According to Cox (2009), teachers' selection of technology should be based on the imperatives of a particular content area. As emerging technologies make available a wider array of technologies for teachers to choose from, they must first consider *how* and *if* their choice is appropriate for the specific content to be taught. Niess (2008) offers a matrix for a process that teachers go through when "clarifying their ideas about content" while developing a lesson with technology (p. 233): (a) declarative, (b) procedural (c) schematic; and (d) strategic. At the declarative level, technology may be used to help students identify (not necessarily simulate) with the targeted content. At the procedural level, teachers choose a technology to help their students think about how to use their content knowledge. At the schematic level, teachers may select technology to guide their students in understanding why and when they might use their new content related knowledge. At the strategic level, teachers may pick a certain technology to afford their students the opportunity to synthesize their new knowledge; students might either create a product or performance that demonstrates their specific content learning.

Another conceptual distinction in the TCK construct is *using technologies that best simulate or represent content domain knowledge*. Mishra and Kohler (2008) contend that technology "has placed a greater emphasis on the role of simulation in understanding phenomena" (p. 15). Technology provides extensive representational opportunities for teachers to display content to their students. For example, science teachers can actually show their students how blood flows through a pumping heart in many Web 2.0 simulations or even in a video. Content can be represented via video, audio, still images presented electronically (LCD, SmartBoard. class website, etc.) and by Internet/Web2.0 tools or applications. These representations exist independent of the teachers' knowledge about their use in a pedagogical context; knowledge of how their choice of technology facilitates content representation is their TCK.

TPK conceptualizes knowledge about how technologies may be used to meet teachers' pedagogical aim(s) in the classroom (Koehler & Mishra, 2008). Specifically, TPK requires teachers to have "forward-looking, creative and open-minded seeking of technology, not for its own sake, but for the sake of student learning and understanding" (p.17). In other words, teachers deeply consider how technologies influence or are influenced by their own pedagogical style and their students' learning styles. As such, the TPK construct is *using technology as part of a pedagogical strategy*. TPK is widely considered to be independent of a specific content or topic not because it doesn't involve content, but it can be applied in any content domain (Cox, 2009; Koehler & Mishra, 2008). Hughes (2008) emphasizes that TPK refers to the use of technology "as a general pedagogical tool" (p. 5229). For example, teachers may use a wiki as a delivery system to provide handouts and rubrics to their students or to take an assessment. These practices meet *general pedagogical aims*. Koehler and Mishra (2008) emphasize that teachers need to "develop skills to look beyond the immediate technology and "reconfigure it" for their own pedagogical purposes" (p. 17). Teachers may ignore the fixed functionality of a given technology (e.g., MSWord or blogs) and leverage these technologies for another pedagogical reason or intention. Koehler and Mishra (2008) also posit that teachers must understand how "learning changes when particular technologies are used" (p. 16). Thus, teachers' TPK might include knowledge of how using technology can better motivate or better engage their students in activities such as cooperative learning. Further, Niess (2008) asserted that teachers with TPK bear in mind students' learning style when choosing a particular technology. For example, teachers may use a video to augment a lesson while supporting visual learners. Therefore, TPK may include: (a) a teacher simply using technology for instruction and classroom management, (b) repurposing particular technologies, and (c) considering student learning when selecting a technology.

TPACK illustrates teachers' ability to engage in a transactional negotiation among their content, pedagogy, and technology knowledge domains (Mishra & Koehler, 2006). Teachers implement new skills and understandings when they combine these knowledge domains while teaching with technology. Koehler and Mishra (2008) also claim that individual components of TPACK (content, pedagogy and technology) are difficult to tease out in teachers' practice. Further, they assert "teaching successfully with technology requires continually creating, sustaining, maintaining and re-establishing a dynamic equilibrium between each component" (p. 20). Therefore, the TPACK construct includes *using pedagogical techniques that constructively and continuously incorporates technologies to teach content.* Ultimately, when teachers' gain a sense of balance, as described above, they are able to *better facilitate* students' *mastery of content* while using *technology*.

Current Application of the TPACK Theoretical Framework in the Literature

Since its inception, TPACK has been adopted as a theoretical framework to describe the various components of knowledge and practice associated with teachers' effective integration of technology across varying content areas. In the following section, brief overviews of select recent studies are presented and discussed to illuminate a cross-section of how the TPACK framework has been utilized throughout the educational research field.

Several studies have looked at how TPACK development impacts teachers in relation to their content area. For example, Niess (2007) investigated how TPACK describes teachers' thinking when attempting to integrate technologies, such as spreadsheets, with specific mathematical content. The study highlights how five teachers' developing TPACK dictated the type of learner outcomes expected for students when teaching mathematics. In addition, Polly and Barbour (2009) describe the influence of professional development on teachers' TPACK and their subsequent math instruction. Two teachers were interviewed and observed teaching mathematics after attending a professional development program that focused on effective technology integration and associated pedagogies. Both participants' technological knowledge (TK) increased as well as their use of technology in their classroom. However, the teachers' use of technology did not facilitate higher-order thinking skills in their students. These findings suggest that teachers' increased proficiency *with technology* doesn't necessarily result in raising their students' conceptual understandings at the highest meta-cognitive levels.

Focusing in another content area, Hughes and Schraber's (2008) case study research found that TPACK development flourishes during meta-cognitive conflict that arises when English/language arts (ELA) teachers wrestle with the interconnections and tensions between technologies and their content. As such, supporting ELA teachers through these pedagogical shifts requires purposefully planned learning experiences, such as course work and/or professional development, which strategically impel teachers toward better decision-making and technology integration. Spires, Hervey and Watson (2009) investigated how an inquiry learning project (ILP) model scaffolded TPACK development in twenty in-service English/language arts (ELA) teachers. Through the scaffolding processes embedded within the ILP process, teachers in the study were "able to move forward with designing classroom activities and selecting and using appropriate instructional technologies for teaching and learning within their ELA content" (p. 32). Taken together, these studies suggest that ELA teachers' foundational TPACK can be strategically increased through planned learning experiences.

In the science classroom, Graham et al. (2009) looked at both pre and post quantitative and qualitative data to describe fifteen teachers' change in confidence in using technology as it related to the TPACK framework. After an intensive professional development experience that focused simultaneously on science inquiry pedagogy and technology use, the researchers detected that "the greatest change in level of confidence was in participants' basic technology knowledge, followed by their TPK, then their TPACK, and finally their TCK" (p. 76). Thus, the TPACK framework helped to delineate the specific changes and pathways in science teachers' emerging professional knowledge.

Hammond and Manfra (2009) described a three-part pedagogical model (i.e., giving, prompting and making) to examine the relationship between pedagogy and technology within the social studies classroom. Their model was intended to augment the TPACK framework by providing "social studies teachers and teacher educators a common language with which to articulate their pedagogical aims" (p. 4) and their choices with technology. Similarly, Harris and Hofer (2009) aligned student-centered "learning activities types" with compatible educational technologies specifically designed to aid in the development of social studies teachers' TPACK. Using learning activity types helped teachers to make "a series of deliberate, balanced, and well-informed pedagogical choices" (p. 7) that incorporated technology in appropriate ways; thus, assisting in their TPACK development and application during social studies instruction.

The TPACK Theoretical Framework and 1:1 Computing Settings

Research studies focused on 1:1 settings helped to highlight how TPACK or "TPACK like knowledge" was emerging in these environments. Currently, researchers conducting studies in 1:1 settings have not used the TPACK theoretical framework to guide their work. Table 1.1 provides an at-a-glance overview of selected studies that were reviewed for this study.

Table 2.1

Selected 1:1 Computing Studies

Authors/Year	**Participants**	**Grade**	**Design**	**Data Sources**
Bebell and Kay/2010	Massachusetts' Berkshire Wireless Learning Initiative	6-12	Mixed methods	Survey data, observations and interviews
Drayton, Falk, Stroud, Hobbs and Hammerman/2010	3 high schools implementing 1:1 computing	9-12	Mixed methods	Questionnaires, teacher logs, teacher vignettes and focus groups
Shapley, Sheehan, Maloney and Caranikas-Walker/2009	21 treatment schools and 21 control/ Texas Technology Immersion Pilot Initiative	6-9	Quasi-experimental	Online teacher questionnaires, observation tools
Oliver, Corn and Osborne/2009	40 classrooms/Early College High Schools implementing 1:1 computing in North Carolina	9-12	Case study	Observation instrument, interviews and focus groups
Maninger and Holden /2009	17 classes implementing 1:1 computing in the Southwest	5-8	Mixed methods	Observation checklist, surveys, interviews
Bebell and Kay/2008	1 school/ Lilla G. Frederick Pilot Middle School Wireless Learning Initiative	6-8	Quantitative	Survey data

Table 2.1 continued.

Authors/Year	Participants	Grade	Design	Data Sources
Zucker and Hug/2008	The Denver School of Science and Technology	9-12	Mixed methods	Survey data, interview and focus groups
Dunleavy, Dexter and Heinecke/2007	4 schools/ 2 in Virginia and 2 in California purposefully selected for their 1:1 computing programs	6-8	Case study	Formal and informal interviews, direct observations, and site documents.
Silvernail and Lane (2004)	243 schools/ Maine's 1:1 Laptop Program	7-8	Mixed methods	Survey data, observations, interviews and document analysis

In the following sections, findings from these studies will be concisely summarized and discussed using the lens of the three sub-constructs of TCK, TPK, and TPACK. Suggested questions are offered, where appropriate, to help guide future research in better capturing richer descriptions of teachers' knowledge while teaching in 1:1 settings.

TCK

TCK is concerned with a teacher's understanding of the interaction of their content and technology – the transformation of content in a given discipline through technological representation that is separate from pedagogical intentions. This type of professional knowledge is difficult to indentify and some researchers are not convinced that it can exist in the mind of someone whose primary focus is teaching (Cox, 2008). Given the nature of methodologies employed in many of these 1:1 studies, namely quantitative measures of teachers' technology use, finding direct evidence of teachers' TCK was difficult.

However, many studies did attempt to measure how teachers used technology to guide students' conceptual development (e.g., TCK) as self-reports of *using of a computer to model relationships or functions* or *using of a computer to help students better understand a concept*. Teachers either reported their use of technology in these ways as the average number of school days per year or on a Likert scale (e.g., 0 = Never; 1 = Once or twice a year; 2 = Several times a year; 3 = Several times a month; 4 = Several times a week; 5 = Everyday). For example, in the Berkshire Wireless Initiative, teachers' self-reports of *using of a computer to help students better understand a concept* increased from 23.6 days up to 46.3 days and *using of a computer to model relationships or functions* increased from 13.0 to 20.8 respectively from 2006 to 2008 (Bebel & Kay, 2010). On these same measures, teachers in the Fredrick Wireless Initiative reported a Likert scale change from 2.3 in 2007 to 3.6 in 2008 and 1.3 in 2007 to 2.0 in 2008, respectively (Bebel & Kay, 2008). Unfortunately, like many studies of 1:1 computing, very little narrative data is available to qualify what is meant or what actually happened in the classroom when participating teachers claim to *use a computer to help students better understand a concept*, etc. In fact, Bebell and Kay (2008) acknowledged, "evaluation teams must add additional survey items to better capture just how teachers are applying their 1:1 resources in their classes" (p. 54). Valuable information about how teachers are using technology for content conceptual development could be better captured by asking the following: Tell me about a time that you used technology to represent or simulate a specific concept in your content area?

Some studies did qualitatively describe how teachers' TCK might be emerging in 1:1 settings. Zucker and Hug (2008) found that "physics simulations assigned by teachers provided graphical information showing the connection between acceleration and velocity. Simulations allowed students to rapidly manipulate variables and observe resulting changes obeying the laws of physics" (p. 7). Similarly, Drayton, Falk, Stroud, Hobbs and Hammerman (2010) shared that "animations, applets, and simulations were frequently reported, in as many as 30% of bi-weekly logs, and 20% of class periods" (p. 32). Specifically, a teacher shared the following: "In biology, for anything that is molecularly based, models of how materials move in and out of cells or how some membranes were built or how they work to facilitate moving the materials in and out— the fact that I can go online and dig up some animations for that is stellar" (p. 33). In Maninger and Holden's (2006) study, a fifth grade teacher elaborated on her TCK: "You kind of have to gear everything [technology] towards your own particular curriculum" (p. 14). A high school physics teacher in the Drayton et al. study (2010) shared his materializing TCK in this way: "the images, especially if they are video clips, can convey an idea of scale and context that is hard to capture in still photos. Thus, some digital images and video have more informational content than illustrations in a text" (p. 32). These limited nature of these examples suggest that teachers' TCK in 1:1 settings may be a rich topic for further investigation. A possible question to better elucidate teachers' TCK in 1:1 environments would be: What is your process for choosing videos, animations or simulations to further content concept development in your students?

These studies did provide some examples of how teachers in 1:1 settings are making pedagogical shifts while using technology to help students fully grasp "unseeable" events.

These teachers' developing sense of the power of "visualizations" that technology can offer has helped to expand their TCK.

TPK

TPK involves teachers' understanding of the affordances and constraints of technologies to meet general pedagogical aims, and knowledge of how selected technology impacts student learning. Many of the selected 1:1 studies captured TPK either quantitatively or qualitatively in the following ways: differentiated instruction and student grouping.

Differentiated instruction. Many teachers in these 1:1 studies have acknowledged the role technology has played in helping them to engage in differentiated instruction that motivates, engages, and increases participation of all their students. This appears to be particularly true for underachieving, at risk, or special education students. According to Maninger and Holden (2009) teachers in their study were "unanimous in reporting that their computers helped them better integrate students with learning difficulties into classroom activities" (p. 13). In another study, a teacher put it this way: "It [1:1 laptop initiative] has freed me up to be more individualized with the kids" (Silvernail & Lane, 2004, p.15). In the same study, one teacher shared how her TPK had evolved in this way:

> I think one of the biggest changes I saw that first year was with my kids with ADHD. I had this one boy; his attention span was less than two minutes. We struggled to get him to focus for over two minutes. When we did our research paper, we used Inspirations. He was the first one to finish his report. I just didn't realize how important that visual piece was. When the screen is up, he can focus on that screen for

longer than two minutes (p. 24).

Teachers in 1:1 initiatives not only have to learn new technologies and tools that require evolving their pedagogical capacities, but they have to evaluate how their choices and actions accommodate individual learning styles and needs of their students. A question to help better illuminate how ubiquitous computing impacts teachers' TPK development might be: How does access to 1:1 technology help you to meet the various and diverse learner strengths and needs your students bring to the classroom?

Interaction and student grouping. Drayton et al. (2010) found that individual teachers' pedagogical styles, not the technology, guided the interactional patterns and student grouping in 1:1 settings. For example, with regard to teacher-led instructional conversations: "teachers who conveyed content and only allowed for students' short questions and responses were reported in all observations" (2010, p. 38). Drayton et al. (2010) also found that small group work occupied less than half the class period in the observations their high schools. For example, in one high school in their study, small group discussions are not reported in 75% of the observations and in the 25% of observed situations where they did occur, they occupied less than half the class period (2010). In their study, Maninger and Holden (2009) found that 5th through 8th graders spent a significant amount of classroom time in whole group instruction. Specifically, students were grouped into dyads or small groups (3+ students) for less than 20% of class time (2009). Oliver, Corn and Osborne (2009) found that even in Early College 1:1 settings that "collaborative work did occur, but was not as frequent as independent and whole group activity"(p.5) took place. Specifically, "the most common instructional grouping across the pilot schools was independent work in 53.5% of classrooms observed, followed by whole group activity in 46.5% of classrooms observed, and finally small group work in 30.2% of classrooms observed" (p. 4). One teacher commented on her ability help students collaborate through group work while using technology:

> Right now we are doing projects with the kid and the computer and that's it. I would like to involve the whole class on the project... maybe with the wiki idea... I need to really figure out how to get the kids involved with each other (2009, p. 4).

Student collaboration on instructional tasks or students co-constructing meaning would seem a natural and necessary outcome of ubiquitous computing environments. In future research, it might be worthwhile to ascertain teachers' perceptions of the drivers and barriers to classroom interaction patterns and student grouping in 1:1 settings in this way: What aspects of a 1:1 setting are conducive for different patterns of interactions or student groupings and why? What aspects are challenging and why?

Teachers in 1:1 setting are slowly, but surely, developing their TPK through embracing opportunities for differentiated instruction and alternative student interactions and grouping made available through their technology.

TPACK

TPACK is teachers' knowledge of the dynamic, transactional negotiation between technology, pedagogy, and content and how that negotiation impacts students' learning in the classroom. Additionally, it highlights the use of technology to enact content-specific strategies, setting it apart from TPK (which utilizes general pedagogical strategies) and TCK (which is independent of pedagogy). Effectively integrating a wide range of technology into teaching requires a consistent set of transformative skills. As such, not many examples of true TPACK were readily identifiable in theses 1:1 studies. Zucker and Hug (2008) asserted that the teachers in 1:1 settings "must understand not only the content (physics, in this case) and effective pedagogy in the domain (including students' common misconceptions), but also how to use various technologies, and how those technologies can be used well to teach and learn the content—a set of skills and knowledge sometimes called 'technological pedagogical content knowledge'" (p. 593). Thus teachers in their study enacted TPACK since computers and related technologies were used continuously to teach and then assess students' understanding of important concepts in physics. For example, simulations allowed students to spend more time on "conceptual understanding and less time on recording data or, in the case of simulations, setting up, calibrating, and using laboratory equipment" (p. 593). In the Silvernail and Lane (2004) study, one teacher reported:

> The MLTI has completely changed my approach to teaching Science. The computer can help my students to collect data, conduct research, investigate the validity of information, make cross-references, etc. These tools have also allowed students to communicate and present material with more depth, knowledge and creativity. The programs provided on the laptops are easy to learn and students always help each other. I would never want to go back to teaching without them. We have come to depend on all they offer (p.14).

These two examples suggest that some teachers in ubiquitous computing environments have risen to the challenge of leveraging technology in dynamic ways to bring about deep student learning. Moving forward, it would be important to ask teachers: How practical is it for you to weave both your TPK and TCK into TPACK? What conditions are necessary for you to do so effectively?

It is important to identify and study supportive conditions in 1:1 settings that may lead to and support further TPACK development in teachers.

Supportive Conditions in 1:1 Contexts

Distinct essential conditions emerged throughout the studies that appear to aid teachers in capitalizing on the availability of 1:1 laptops to effectively increase student learning. These same conditions may potentially help to further teachers' TPACK development as well. For these studies, however, it is impossible to delineate which supportive conditions were instrumental for further development in specific sub-constructs of the TPACK framework. The conditions that surfaced throughout these studies will be presented and discussed in the following sections: (a) 1:1 immersion phase, (b) leadership, (c) professional development, and (d) community.

1:1 immersion phase. After several years of studying schools involved with Apple's Classrooms of Tomorrow, Dwyer, Ringstaff and Sandholtz (1990) identified distinct phases that were aligned with "new patterns of teaching and learning" (p.4) during a school's immersion in a 1:1 initiative. These phases, *entry*, *adoption*, *adaption*, *appropriation* and *invention* helped to describe overall patterns of change and related accommodating conditions experienced by teachers. In the *entry* phase, teachers are generally trying to organize their radically transformed physical environments. In the *adoption* phase, teachers struggle to master the many skills and ideas that successful effective technology integration requires. In the *adaption* phase, teachers begin to use technology in engaging their students in higher-level thinking and product generation. In the *appropriation* phase, teachers fully understand their technology and use it effortlessly to support students' learning. In the *invention* phase, teachers are "ready to invent interdisciplinary learning activities that engage students in gathering information, analyzing and synthesizing it, and ultimately building new knowledge on top of what they already know" (p. 9). Similar to what Dwyer, Ringstaff and Sandholtz (1990) found, the pace of change was slow and uneven, both in individual classrooms and within the school culture in the selected 1:1 studies that I reviewed. With one exception, the schools and cultures involved in the majority of these selected 1:1 studies, even those in the 3rd and 4th year of implementation, appeared to fall in the *adoption* phase. Many teachers reported having difficulty maximizing their access to laptops to facilitate complex and enriching instructional activities. For example, Dunlevy, Dexter, and Heinecke (2009) observed a teacher "assign comprehension questions on a worksheet using an online version of the text "Treasure Island"…then after relating the instructions, the teacher provided no additional coaching or instruction and spent the remainder of the class sitting at her desk completing other tasks" (p. 13). In addition, teachers' overwhelming use of whole group instruction versus collaborative small group or project-based instruction also indicated that many of the schools were in the *adoption* phase. These findings suggest that a school's immersion phase may have influenced how its teachers leveraged technology in their classrooms. Thus, teachers' TPACK development will be similarly impacted.

Leadership. Effective leadership emerged as a supportive condition across all the 1:1 studies that I reviewed. Specifically, Drayon et al. (2010) found that "informed and consistent administrative policy ... helped create the conditions necessary for the maturation of these experiments with ubiquitous computing" (p. 44). Bebell and Kay (2010) found that the lack of leadership support led to unsuccessful 1:1 implementation in one of the five pilot schools included in their study. Specifically, they reported that "without any clear leadership concerning the management and oversight of the pilot program ... teacher and student technology use was regularly lowest in the student and teacher surveys" (p. 50) at the one school. Silvernail and Lane's (2004) study revealed that "the presence of one or more key individuals in the schools who have served as champions of the laptop program and have provided strong leadership during implementation of the 1:1 program" (p. 33) contributed overwhelmingly to these schools' overall success. Strong administrative leadership has consistently proven to be key in effectively supporting 1:1 initiatives and, thus, may have the same impact on teachers' TPACK development.

Professional development and collaboration. Across the selected 1:1 studies, teachers reported that professional development helped them improve their confidence and ability to use technology in more relevant and effective ways. Bebell and Kay (2010) found that teachers felt better supported when the focus of professional development vacillated between learning how to use new technology tools and how to integrate that technology into their curriculum. "Receiving informal help from colleagues" (p. 16) was rated the highest across all forms of professional development and/support in the MLTI study (Silvernail et al., 2010). Similarly, teachers claimed that "seeing what other teachers were doing and how they were implementing technology" (Shapley et al., 2010, p.104) better supported improvements in their own instructional practices. These findings echo what Hughes (2005) suggested is an essential element in support teachers using technology; she asserted that schools should "promote active engagement with other teachers" (p.23). Curriculum focused professional development along with increased collaborative interactions appears to help teachers better realize the benefits of the technology available in their 1:1 setting. Therefore, communication and collaboration, along with ongoing professional development, may be as helpful in aiding teachers' TPACK development.

Survey of Preservice Teachers' Knowledge of Teaching and Technology: A TPACK Survey

In 2009, Schmidt et al. published a study about their *Survey of Preservice Teachers' Knowledge of Teaching and Technology.* The survey was developed as self-reported measure of PK – 6th grade pre-service teachers' knowledge of the domains within the TPACK theoretical framework. The survey items ask teachers to rate the extent to which they agree or disagree with statements in relation to their practices when using technology for teaching and learning. Items were content specific (e.g., I can teach lessons that appropriately combine science, technologies and teaching approaches) and/or content general (e.g., I can choose technologies that enhance the content for a lesson). Teachers used the following five point Likert scale: (1) strongly disagree; (2) disagree; (3) neither agree nor disagree; (4) agree; and (5) strongly agree with each item. The survey contains seven sub-scales: pedagogical knowledge (PK), content knowledge (CK), technology knowledge (TK), pedagogical content knowledge (PCK), TCK, TPK, and TPACK. The content validity of the items was established in collaboration with three nationally known researchers with expertise in TPACK (Schmidt et al., 2009). Schmidt et al. collected administered the survey to 124 students enrolled in an instructional technology course at a large midwestern university. The research team used the following statistical analyses to establish validity and reliability of the instrument: (a) each TPACK knowledge domain subscale was assessed for internal consistency using Cronbach's alpha reliability technique, (b) the construct validity for each knowledge domain subscale was established using principal components factor analysis, and (c) the relationship between TPACK domain subscales was examined using Pearson product-moment correlations (a full description of these results will be presented in Chapter Three). The authors asserted that the survey is a valid and reliable measure of PK-6 preservice teachers' TPACK.

Schmidt et al. acknowledged that "continual revision and refinement of the instrument, including the addition of more items to some of the TPACK subscales" (p. 137) is called for use with secondary teachers. Specifically, the PCK and TCK subscales had only four items, and each item was tied to a specific content area. For example, the original statements in the TCK subscale were:

- I know about technologies that I can use for understanding and doing literacy.
- I know about technologies that I can use for understanding and doing social studies.
- I know about technologies that I can use for understanding and doing science.
- I know about technologies that I can use for understanding and doing mathematics.

In addition, the TPACK subscale had four of eight content specific questions, written in a similar pattern as the TCK items (e.g., I can teach lessons that appropriately combine mathematics, technologies, and teaching approaches). Unlike PK-6 teachers who generally teach all subjects in their classrooms and are able to rate themselves on all items in the above TCK subscale, secondary teachers are often experts in only one content area. Therefore, it seemed appropriate to create separate item subsets in the subscales for PCK and TCK in the content areas of mathematics, science, social studies, and English by adding additional questions to the current survey (a full description of these procedures will be presented in Chapter Three).

Exploration of new instruments is a continuous process often requiring a progression through three distinct stages: substantive, structural and external (Benson, 1998). Moving forward, research that uses an adapted *Survey of Preservice Teachers' Knowledge of Teaching and Technology*, particularly with secondary teachers, will benefit from efforts that tackle issues specific to the structural stage of survey development. Specifically, the objective of this stage is to determine the extent to which items contained in an instrument covary among themselves, and how they covary with the intended structure of the theoretical framework (1998). Covariance can provide a measure of the strength of the correlation between two or more items in a subscale or between the subscales themselves. Generally, statistical methods used to accomplish this goal include conducting Chronbach's alpha analysis, inter-item and item to total correlations along with exploratory factor analysis. Future research involving measurement of secondary teachers' TPACK would benefit from these efforts.

Summary

It appears that experienced teachers might need to diligently consider their own professional knowledge, particularly as more technology integration is called for, and as 1:1 laptop computing initiatives become pervasive in K-12 education. The TPACK framework provides a lens to identify teachers' new knowledge as well as related instructional practices across content areas and contexts. This model radiates with opportunities to examine how experienced teachers' long held pedagogical and content knowledge is reshaped to include technological knowledge. Taken together, the TPACK literature reveals patterns that emphasize a need for continued and specific research investigating veteran teachers' TPACK and instructional practices in 1:1 settings. The TPACK framework offers a theoretical and coherent structure in which to identify, describe, and measure veteran teachers' professional knowledge around technology innovations and practice in their 1:1 classroom. Developing a TPACK survey that is both valid and reliable for secondary teachers is also needed.

It is also clear that when researchers try to evaluate the educational uses and impact of technology in 1:1 settings, broader pedagogical knowledge development and supportive conditions can also be examined. The development of TCK, TPK, and TPACK does not occur in single, isolated, or discrete processes. Rather, a combination of conditions and experiences that make it highly probable these teachers will be able to effectively use technology to support students' learning and achievement. It is important to examine of veteran teachers' experiences while they practice in 1:1 settings.

CHAPTER THREE: METHODOLOGY

The purpose of this study was to discover secondary veteran teachers' self-reported technological content knowledge (TCK), technological pedagogical knowledge (TPK) and technological pedagogical content knowledge (TPACK) and their practices in 1:1 settings. Measures of secondary veteran teachers' TPACK knowledge and practice in 1:1 have not been made available in the literature. Moreover, no valid and reliable instrument has been made available to study secondary teachers' TPACK. This study explored the following three questions:

1. How do revisions made to the *Survey of Teachers' Knowledge of Teaching and Technology* impact its reliability and validity for use with secondary teachers?
2. What are the self-reported levels of secondary veteran teachers' technological pedagogical content knowledge (TCK, TPK, and TPACK) practicing in 1:1 settings?
3. How are veteran teachers' technological pedagogical content knowledge (TCK, TPK, and TPACK) reflected in their instructional practices implemented in 1:1 settings?

Research Design

To gain an in-depth understanding of veteran teachers' TCK, TPK, and TPACK in 1:1 settings, I employed a mixed methods explanatory sequential design (quan → QUAL). The purpose and rationale for each aspect of this study's design are discussed in the sections that follow.

Mixed methods research designs attempt to better understand real-world phenomena found throughout psychological, social, and educational fields. Mixed methods research designs permit deeper exploration of educational research questions as they incorporate very effective techniques from both quantitative and qualitative traditions (Tashakkori & Teddlie, 2003). Mixed methods research designs are quickly becoming a prevalent approach to study 21st century educational problems (Johnson & Onwuegbuzie, 2004). Specifically, mixed methods research designs are well suited for investigating complex processes such as teachers' knowledge formation and practice along with emerging 21st century theoretical phenomena (e.g., TPACK). Specifically, mix methods designs are adept in answering "what" and "how" types of research questions (Creswell & Plano-Clark, 2007). For example, mixed methods researchers are encouraged to collect multiple data using different strategies, approaches, and methods in such a way that the final mixture or combination will result in *complementary* strengths and minimal weaknesses (Johnson & Turner, 2003). As such, mixed methods research designs help to produce more holistic pictures of the phenomena under study than a mono-method research design.

A *sequential explanatory mixed methods design* enables researchers to use the qualitative results to expand understandings of or build upon initial quantitative results, as well as enhancing the knowledge base for the theoretical framework guiding the study (Creswell & Plano-Clark, 2007). I collected and analyzed the quantitative data in the first phase. During the connecting phase, I used the quantitative results to create sampling pools to aid in purposeful case selection for the following qualitative phase (2007; Creswell, Plano-Clark, Gutman, & Hanson, 2003). Purposeful sampling seeks information-rich cases that can be studied in depth (Patton, 2002). Follow-up cases allowed me, through observation in natural settings, direct access to the participants' thoughts, feelings and behaviors rather than just conducting a narrowly focused examination of their aggregated or disaggregated data that I collected in the initial quantitative phase.

Participants

Participant recruitment was conducted through the 1:1 Learning Collaborative housed in The William and Ida Friday Institute for Education Innovation (http://www.fi.ncsu.edu/project/nc-11-learning-collaborative/). The Friday Institute serves as the innovative education research arm in the College of Education at North Carolina State University. The 1:1 Learning Collaborative provides ongoing implementation support along with face–to–face and online professional development to superintendents, administrators and teachers participating in the 1:1 computing North Carolina Learning and Technology Initiative (NCLTI). To access potentially appropriate study participants, the 1:1 Collaborative provided me with 455 secondary teachers' email addresses gleaned from their NCLTI database. I sent all 455 teachers an email with a link to the adapted *Survey of Preservice Teachers' Knowledge of Teaching and Technology* (described in detail in the next section) on May 17, 2011. Three subsequent reminders to non-respondents were emailed on June 9, July 19 and August 19, 2011. A total of 156 teachers took the survey. For this study, veteran teachers were defined as having eight or more years of experience. Many attempts were made to rationalize this benchmark by looking at statewide teacher attrition rates in North Carolina that may have been correlated to veteran teachers choosing to leave the profession as technology requirements increased. Rather data indicated that high numbers of beginning teachers leaving are leaving, and then declines with each year service (Corbell, 2009). As such, I settled on a simple algorithm of doubling the number of years required (e.g. four years) to achieve tenure in North Carolina to select "veteran teacher" participants. 91 of 156 teachers who completed the survey met this criterion. In the connecting phase of this study, I used purposeful sampling to identify information-rich cases from these 91 secondary veteran teachers (Patton, 1990). Specifically, I selected three cases with two teachers per construct (e.g. TCK, TPK, and TPACK). For example, the TCK case was comprised of one veteran teacher who self-reported high TCK and one teacher who self-reported low TCK in their responses on the adapted *Survey of Preservice Teachers' Knowledge of Teaching and Technology*.

How I carried out data collection and analysis are fully outlined in the following section.

Data Collection and Analysis

Description, rationale, procedures, advantages, limitations of each data source along with analysis procedures are presented and discussed as follows: (a) quantitative phase: data sources and analysis; (b) connecting phase: participant pool formation; (c) qualitative phase data sources and analysis.

Quantitative Phase: Data Sources and Analysis

The first aim of this study's quantitative phase was to establish emerging reliability and validity in the adapted *Survey of Preservice Teachers' Knowledge of Teaching and Technology* created for this study. The second aim was to examine and provide an account of the self-reported levels of TCK, TPK, and TPACK from the 91 participating veteran teachers' practicing in 1:1 settings.

Data source: A survey of teachers' knowledge of teaching and technology. Schmidt et al. (2009) developed the *Survey of Teachers' Knowledge of Teaching and Technology* using PK-6 preservice teachers. Teachers used a five-point Likert scale (e.g., strongly agree to strongly disagree) to evaluate items that contained statements about teaching with technology. The survey contained seven sub-scales: pedagogical knowledge (PK), content knowledge (CK), technology knowledge (TK), pedagogical content knowledge (PCK), TCK, TPK, and TPACK. Items were content specific (e.g., I can teach lessons that appropriately combine science, technologies and teaching approaches) and/or content general (e.g., I can choose technologies that enhance the content for a lesson). Schmidt et al. (2009) asked three researchers with extensive TPACK experience to help with establishing the content validity of the subscales. These TPACK content experts provided Schmidt et al. with item revisions that ranged from changing the position of a word to turning a single item into several related items. The resulting survey had 47 items and seven subscales (e.g., TK, CK, PK, PCK, TCK, TPK, and TPACK). Initially, Cronbach's Alpha coefficients were used to examine the internal consistency for items within each domain subscale. Questionable or problematic were items eliminated. The resulting internal consistency reliability ranged from .75 to .92 for the seven TPACK subscales. Pearson product-moment correlations were conducted to examine the relationship between the TPACK domain subscales. The highest correlations were between TPACK and TPK ($r = 0.71$), TPACK and TCK ($r = 0.49$), and TPACK and PCK ($r = 0.49$). Schmidt et al. used "factor analysis with varimax rotation within each knowledge domain and Kaiser normalization" (p. 130) to ascertain the covariation among the items and whether the patterns fit well into the TPACK constructs. Factor loading for items within each subscale ranged from .52 to .91. Although, more widely accepted medium loadings of .30 - .40 would have been preferred (Sass, 2010), for the purposes of this study, the TCK, TPK, and TPACK subscales did exhibit strong internal consistency reliability. Specifically, the Cronbach's alphas for these subscales were .86, .80 and .92 respectively. The above-described analyses led me to believe that the *Survey of Teachers' Knowledge of Teaching and Technology* was a reliable measure of TCK, TPK and TPACK. However, Schmidt et al. did recommend that researchers conduct studies that pair survey data with observations of teachers' instructional practices to further establish the survey's validity. The authors also suggested that adding items to the PCK and TCK subscales for use with secondary teachers.

In fact, I did adapt the survey by writing additional items for the PCK and TCK subscales for use with secondary teachers. To provide context for the reader, the original four items in the TCK subscale were as follows:

- I know about technologies that I can use for understanding and doing literacy.
- I know about technologies that I can use for understanding and doing social studies.
- I know about technologies that I can use for understanding and doing science.
- I know about technologies that I can use for understanding and doing mathematics.

PK-6 preservice teachers would generally be able to rate themselves on all items in the above TCK subscale, however many secondary teachers could not. Therefore, I created two additional items based on the language patterns of original items and definitions of PCK and

TCK. The additional PCK items were (a) I can select effective teaching approaches to illustrate difficult concepts within my content area and (b) I can select effective teaching approaches that reflect my students' prior knowledge. The additional TCK items were (a) I know about technologies that can deepen students' content area knowledge and (b) I know about technologies that I can use to represent concepts within my content area. The single content specific items from the original survey in combination with these additional two items formed new content specific item subsets within the PCK and TCK subscales. For example, a subset of items, appropriate for secondary English teachers within the TCK subscale, was:

- I know about technologies that I can use for understanding and doing literacy.
- I know about technologies that can deepen students' content area knowledge.
- I know about technologies that I can use to represent concepts within my content area.

The TPACK questions used in the adapted survey were four of the eight original questions that were not content specific:

- I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn.
- I can use teaching strategies that combine content, technologies, and teaching approaches.
- 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 and teaching approaches that enhance the content for a lesson.

In the first phase of my study, this adapted version of the *Survey of Teachers' Knowledge of Teaching and Technology* (see Appendix C) was administered electronically using Survey Monkey (http://www.surveymonkey.com/AboutUs.aspx).

Quantitative analysis. Missing or incomplete responses were removed from the collected survey data. I conducted descriptive analyses (e.g., mean, standard deviation, skew) on the data using Predictive Analytics SoftWare (PASW). Some responses were removed to create a more normally distributed sample (the details are fully explained in Chapter Four). An exploratory factor analysis was planned to analyze patterns within each domain subscale address this study's first research question (i.e., How do revisions made to the *Survey of Teachers' Knowledge of Teaching and Technology* survey impact the reliability and validity of the instrument for secondary teachers?). Instead, Cronbach's alpha coefficients along with item- to-total correlations and inter-item correlations were used to examine internal consistency in each of the adapted survey's subscales. A full explanation the EFA analysis, along with the rationales for subsequent decisions made, can be found in Chapter Four. Means and standard deviations for teachers' self-reported TCK, TPK, and TPACK are also presented, analyzed, and discussed in Chapter Four that addressed my second research question (i.e., What are the self-reported levels of secondary veteran teachers' technological pedagogical content knowledge (TCK, TPK, and TPACK) practicing in 1:1 settings?).

Connecting Phase: Participant Pool Formation

During the connecting phase of this study, I employed a series of systematic procedures to purposefully identify information-rich cases for the qualitative phase of this study. I first transformed participants' TCK, TPK, and TPACK raw scores to z-scores using PAWS. I applied the simple algorithm of *one standard deviation above or below* to teachers' TCK, TPK, and TPACK z-scores to identify potential participant pools. For example, teachers with TCK z-scores at +1.00 or higher would form the participant pool for the self-reported high "TCK" teacher in the TCK case. The second teacher for the TCK case came from the pool of teachers with TCK z-scores of -1.00 or below. I believed that this technique would help me identify participants with contrasting TCK, TPK and TPACK. However, some participants' z-cores made them eligible in more than one pool. For example, a teacher with a TCK z-score of + 1.00 often had z-scores of +1.00 in TPK and TPACK as well. As such, any entry point for pool formation could eliminate potential participants as they may have been selected for another construct. I decided to use the largest z-scores found among the TCK, TPK, and TPACK subscales as the entry point for pool formation. The TCK subscale had the largest participant' z-score. As such, five teachers with the highest +1.00 TCK z-scores and 5 teachers with the lowest – 1.00 TCK z-scores were selected as the first participant pool for the TCK case. These 10 teachers, therefore, were ineligible for the TPK and TPACK pools (A detailed description of this process, including actual z-scores can be found in Chapter Four). I emailed the teachers identified each of the high/low TCK, TPK, and TPACK pools on October 12, 2011. This email queried these teachers about their wiliness to participate in the quantitative phase of this study. I received two negative responses due to a change in jobs (i.e. the teacher was no longer in the classroom at their school or was no longer teaching at the secondary level beginning in the 2010-2011 school year). Six teachers, one from each pool, were willing to participate. I used follow up email correspondence to arrange for qualitative data collection with each of these teachers. Most of the interviews with these teachers took place immediately after I observed their lesson. One interview occurred several hours after the observation. I have provided the dates of the observations and interviews in Table 3.1.

Table 3.1

Observation and Interview Schedule

TPACK Construct	Date
TCK self-reported "high" teacher	10.18.10
TCK self-reported "low" teacher	11.15.10
TPK self-reported "high" teacher	11.05.10
TPK self-reported "low" teacher	11.12.10
TPACK self-reported "high" teacher	11.05.10
TPACK self-reported "low" teacher	10.25.10

Qualitative Phase: Data Sources and Analysis

The data collected and analysis conducted in this phase was intended to support the discovery of new information in answering the third question guiding this study (e.g., How are veteran teachers' technological pedagogical content knowledge (TCK, TPK, and TPACK) reflected in their instructional practices implemented in 1:1 settings?).

Data source: Videotaped classroom observations. I used an HD Flip camera to videotape a single lesson presented by the six teachers participating in the qualitative phase of this study. The average length of each lesson was 55 minutes. Observations enable researchers to see things that participants themselves are not aware of, or they are unwilling to discuss (Patton, 2002). Specifically, videotaped observations can capture the illusive qualities of teaching that separates one teacher and from another (Rosenstein, 2002). Videotaped observations become permanent records that can be analyzed multiple times, yielding opportunities for new insights and confirmation of coding and emerging themes. The videotaped observations were used to triangulate emerging findings from the study; they were used in combination with interview data and field notes to substantiate findings. In this study, *videotape as the data* provided additional thick descriptions of the context, specific incidents and/or behaviors relating to teachers' self-reported TCK, TPK, and TPACK (Powell, Francisco, & Maher, 2003). Any type of observation has limitations. For example, the very act of my observation had the potential to invoke better performance from the teachers in this study (i.e., Hawthorne Effect). That is, these teachers may have planned an atypical lesson in expectation of being observed.

Before any data collection began, all six teachers signed informed consent forms for phase two of this study (see Appendix B) and were provided copies. I discussed with each teacher what I would actually be doing during the observation and how confidentiality for video and audio files would be handled as outlined in their informed consent form.

Data Source: Stimulated recall interviews. I asked teachers to participate in stimulated recall interviews (SRIs) as soon as possible after their videotaped classroom observations. The video files were downloaded and then played on my password-protected computer. I gave directions to the teachers prior to viewing a video (e.g., "*Please provide me with your objectives and intentions for the lesson, and comment on any ideas, beliefs or theories that you can identify that influenced your planning and teaching approach*" (based on Lyle, 2003). While viewing the taped lesson, teachers were directed as follows*: "As you view the videotape, please walk me through the lesson and tell me what was going on in your mind at the time. Try to distinguish between any thoughts you had at the time and thoughts you're having now as you watch the tape and make me aware of those differences. You can stop the video as often as you like and for as long as you need to explain your thinking"* (based on Kane et al., 2004).

Since thinking aloud during teaching is rather difficult, SRIs offer one way to capture teachers' thinking during instruction (Ethel & McMeniman, 2000; Lyle, 2003). In SRIs, video or audio of a lesson are immediately played after the lesson to stimulate the revival of thoughts the teacher had prior and during teaching. Studies have shown that SRIs are useful for tapping into the implicit knowledge teachers' possess (2000; 2003; Meade & McMeniman, 1992). Moreover, joint viewing of the video footage can deepen a researcher's understanding of teachers' practice and thinking through reflective dialog (Rosenstein, 2002). The SRIs helped me glean profound insight into what aspects of TCK, TPK, and TPACK guided teachers' pedagogical choices prior to and during instructional practices that I captured on video.

Data source: Semi-structured interviews. Semi-structured interviewing utilizes open-ended questions that allow for individual variations for interpretations of their reality (see Appendix D). Follow-up questions were an important part of this study's process to capture the complexities veteran teachers experience when they teach and learn with technologies within their 1:1 classroom and school. Their experiences are part of their practice. For this study, immediately following their SRI, I engaged each teacher in a semi-structured interview to elicit additional information, feelings or thoughts about their 1:1 environment. These interviews were guided by a set of questions (see Appendix D) and averaged 10-15 minutes.

Both simulated and semi-structured interviews were audio taped using Audacity, a free audio recording application. Audacity created MP3 audio files of each teacher's interviews that were then saved on my password-protected computer.

Data source: Field notes. Field notes are transcribed notes taken during and after observations and interviews. There are many styles of field notes, but all field notes generally consist of two parts: descriptive, in which the observer attempts to capture a word-picture of the setting, actions and conversations; and reflective, in which the observer records thoughts, ideas, questions and concerns based on the observations and interviews.

Qualitative data analysis. I had intended to complete within-case analysis of videotapes, transcripts and field notes in two ways: (a) *a priori* analysis (all data sources) and (b) open-coding to discover unique emerging themes. However, I encountered two issues that impacted the within-case analysis as originally planned.

First, I planned to conduct a within-case *a priori* analysis of all data source, including the semi-structured interview data. I thought that semi-structured interview data would help to highlight certain supportive conditions or professional activities that ***specifically*** furthered their respective TCK, TPK, or TPACK development. This, however, proved difficult. For example, when interviewing the self-reported "low" TPACK" teacher, I asked, "How would you describe the level of technology support available in your school? How does this effect your development of TPACK?" The participant replied, " I don't know what that is." I felt that if I explained what I meant, I would overly influence the participants' response. Further, in my first field note, I had noted the teacher was unable to articulate how the events and experiences in her 1:1 directly impacted her TCK development. Despite these missteps, I felt continuing to capture veteran teachers' professional experiences as part of their practice in 1:1 settings was imperative for this study. As such, I replaced TCK, TPK, or TPACK with "leveraging technology" or "technology integration" when asking questions in subsequent semi-structured interviews. I must disclose, that as matter of habit, I accidently used the TPACK acronyms during the remaining interviews, but quickly rephrased the question as described above.

Second, ***unique*** themes or categories, apart from *a priori* coding, did not emerge during open coding of transcript, video, and field note data. For example, during their SRI, both teachers in my TCK case made very similar comments about "wanting students to see it [content concept]." They were attempting to provide a rationale for why they leveraged multimedia technology during their lesson. Well, "content representation" is a hallmark of the TCK construct. Further, both my TPK teachers used technology when assessing student learning so I attempted to code data into an emerging "assessment" theme. After thoughtful consideration, however, I could not separate the idea of teacher conducting "assessment" from the conceptual distinctions associated with TPK.

Detailed explanations of the actual within and cross-case analyses, aided by ATLAS ti, are provided in the following sections.

Within-case analysis. In an attempt to answer the third research question (e.g., How are veteran teachers' self-reported technological pedagogical content knowledge (TCK, TPK, and TPACK) reflected in their instructional practices implemented in 1:1 settings?), I engaged in systematic and iterative data analysis of videotape, SRI interview transcripts and field note data. The TPACK framework has shaped the research questions as well as the design and methodology, including case selection, of this study. TPACK is, of course, quite a complex synthesis of teacher' knowledge of curriculum content, teaching strategies and the affordances and constraints of technological tools and resources along with the context of the classroom, including social, political, and cultural factors. As such, I believed that a substantive a priori coding schema (e.g. analytic components and markers) was necessary both reveal and explain the data captured in this study. In fact, Yin (2003) recommends "analytic generalization...in which a previously developed theory is used as a template with which to compare the empirical results of the case study" (p. 31). Storberg-Walker (2008) claimed that "from a qualitative research perspective each analytical component must be unique -- it is necessary to define/specify each component so there is no overlap in definitions...Unique elements require explicit definitions and distinctions in order for researchers to code data" (p. 567). During analysis of the data, I sought to identify teachers' thinking and instructional practices related to the TPACK framework and relevant research. Therefore, establishing TCK, TPK, and TPACK *a priori* codes, as analytic components and markers associated with their conceptual distinctions discussed in Chapter Two, helped to focus my attention on certain data and to ignore other data. In the following sections, I provide a brief overview of each of the TPACK constructs and associated analytic components and markers used in the within-case coding process for this study.

TCK codes. TCK conceptualizes a teachers' understanding of how the application of technology can directly support student skill development in a given discipline; teachers firmly grasp the reciprocal relationship between technology and content learning (Mishra & Koehler, 2006). The first analytic component in the TCK construct used in this study was *using technologies best suited for addressing content learning.* Every technology choice made by teachers "affords and constrains the types of content ideas that can be taught" (Koehler & Mishra, 2008, p. 16). Therefore, teachers' selection of technology should be based on the imperatives of their particular content area.

The markers for the *using technologies best suited for addressing content learning* analytic component were: (a) declarative, (b) procedural (c) schematic; and (d) strategic. These four markers are based on a process matrix that Niess (2008) suggested teachers use for "clarifying their ideas about content" while developing instructional activities with technology (p. 233). In an instructional activity at the declarative level, technology may be used to help students identify (not necessarily simulate) with the targeted content (2008). Teachers may choose a technology to help their students think about how to use the content knowledge in an instructional activity at the procedural level (2008). In an instructional activity at the schematic level, teachers may select technology to guide their students in understanding why and when they might use their new content related knowledge (2008). Teachers may pick a certain technology that affords their students the ability to synthesize their new knowledge to either create a product or a performance that demonstrates their specific content learning at the strategic level (2008).

The second analytic component of TCK construct applied in this study was *using technologies that best simulate or represent content domain knowledge*. Mishra and Kohler (2008) insist that technology "has placed a greater emphasis on the role of simulation in understanding phenomena" (p. 15). That is, technology provides extensive representational opportunities for teachers to display content to their students. To delineate the actual type of technology used in the lessons, four markers were established: (a) content was represented via video, (b) content was represented in audio only, (c) content was represented by images (LCD, SmartBoard. class website, etc.) and; (d) content was represented directly by the Internet/Web2.0 tool or application.

TPK codes. TPK conceptualizes the knowledge about how technologies may be used to meet teachers' pedagogical aim(s) in the classroom (Koehler & Mishra, 2008). Specifically, TPK requires teachers to have "forward-looking, creative and open-minded seeking of technology, not for its own sake, but for the sake of student learning and understanding" (p.17). In other words, teachers deeply consider how technologies influence or are influenced by their own pedagogical style and their students' learning styles. The analytic component for the TPK construct used in this study was *using technology as part of a pedagogical strategy*. The markers for this analytic component were: (a) general pedagogical aim, (b) repurposing; and (c) considering student learning.

TPACK codes. TPACK illustrates teachers' ability to engage in a transactional negotiation among their content, pedagogy, and technology knowledge domains (Mishra & Koehler, 2006). Teachers implement new skills and understandings when they combine these knowledge domains while teaching with technology. The analytic component in the TPACK construct used in this study was *using pedagogical techniques that constructively and continuously incorporate technologies to teach content.* The singularity of this analytic approach, with no markers, was based on Koehler and Mishra's (2008) claim that the individual components (e.g., content, pedagogy and technology) are difficult to tease out in a teachers' actualization TPACK.

Table 3.2 provides the TPACK framework aspects, analytic components, markers, and codes used in the within-case analysis for this study.

Table 3.2

Within-case Coding Scheme Based on TPACK Framework and Related Research

TPACK Domain	Code	**Analytic Component**	Code	**Markers**	Code
TCK	C	*Using technologies best suited for addressing content learning*	C1	Declarative	C1a
				Procedural	C1b
				Schematic	C1c
				Strategic	C1d
TCK	C	*Using technologies that best simulate or represent content domain knowledge*	C2	Content represented via video	C2a
				Content represented in audio	C2b
				Content represented by still images (LCD, SmartBoard. class website, etc.)	C2c
				Content represented by Internet/Web2.0 tool or application	C2d

Table 3.2 continued.

TPACK Domain		**Analytic Component**		**Markers**	
	Code		Code		Code
TPK	P	*Using technology as part of a pedagogical strategy*	P1	General pedagogical tool	P1a
				Repurposing	P1b
				Considering student learning	P1c
TPACK	T	*Using pedagogical techniques that constructively and continuously incorporates technologies to teach content*	T1		

Before I began within-case coding, I viewed each teacher's video several times followed by a reading of his or her respective interview transcripts and field notes. I wanted to become completely familiar with the content of all data associated with each teacher. Moreover, in this phase, I used memoing to record critical events in the video to serve as a point of reference for subsequent coding. According to Powel, Francisco, and Maher (2003), "an event is critical in its relation to particular research questions pursued" (p.418). I considered any time that the teacher used technology while teaching or directed students to use technology to be a critical event in the video data. These memos helped to organize and refine how these video data were later coded in relation to the TCK, TPK, and TPACK constructs.

After completing my critical event memos, I made a "first pass" at coding in which selected data was assigned to one of the aspects of TCK, TPK, and TPACK depending on the case being analyzed. Then, on a second pass, data were coded according to analytic components extracted from the TPACK framework and related research as shown in Table 3.2. On the third pass, as needed for further granulation, data was coded using markers as shown in Table 3.2. For instance, the quote, "students can get all the meanings the word can have, and then they can apply it to our story" was first coded according to the aspect of "C." Then the quote was coded using the appropriate analytic component *"using technologies best suited for addressing content learning"* as "C1." Finally, I coded the quote using the appropriate marker of "technology to help students think about how to use the content knowledge". The final code, then, according to the coding scheme provided in Table 3.2, was "C1b."

Some video, SRI transcripts, and field note data proved challenging, usually too vague, to code to the finest level – that of the markers – but still fit within a TPACK aspect and its accompanying analytic components. It is important to note that according to Rosenstein (2002) video allows "a researcher to make more direct connections between observable behaviors and interpretations" (p. 728; as cited in Powell, Francisco & Maher, 2003). Therefore, in an effort to triangulate the data, the same code used on teachers' SRI transcript (where they clearly referred to a segment or activity in their videotaped lesson), was applied to the video and related field note data where applicable.

Cross-case analysis. Next, cross-case analysis was conducted. Through an inductive process, I coded the semi-structured interview data using a common approach in qualitative research: *open coding.* Open coding is "the analytic process through which concepts are identified and their properties and dimensions are discovered in data" (Strauss & Corbin, 1998, p. 101). Open coding is a process of reducing the data to a set of categories that appear to describe the phenomenon found in the participants' responses. I read each semi-structured interview carefully. I listed significant statements; Experiences in 1:1 settings that were important to the teachers and/or comments that were repeated in several interviews were listed. Following the constant comparison method, and before adding a new quote to a category, I compared it to each of the other quotes that were part of that category and reasoned through its inclusion or the initiation of a new initial category (Patton, 2002). Gradually, six categories were revealed: leadership stance, professional development experiences, help with technology, being a veteran teacher, teachers' attitude towards 1:1 initiative, and teachers' self-efficacy for using technology. During a second reading of the comments associated with an initial category, as shown in Table 3.3. I created subcategories to highlight the various dimensions within each initial category. Then, I coded the data using these subcategories using constant comparative method. Next, I clustered the coded data into themes based on their relevance to the study. In all, 14 codes were established and 3 interpretive themes emerged from the data. A full description of findings associated with cross-case analysis is presented in Chapter Four.

Table 3.3

Cross-case Open Coding Scheme

Initial Category	**Subcategories (Final Codes)**
Leadership stance	Get the technology needed by their teachers
	21st century skill focused
Professional development experiences	It's mandatory
	Not content specific
	We get to choose
	We get to practice together
Help with technology	Kid's don't get penalized (i.e. laptops)
	Opening websites
Being a veteran teacher	Can't be a leader
	Different generations
Teachers' attitude towards 1:1 initiative	Can't live without it
	Helps with assessment
Teachers' self-efficacy	I can vary my instruction
	I know I can use technology

Validity and Reliability – Trustworthiness

The best approach to address concerns about validity and reliability is thoughtful contemplation about the ways data are handled and approached (Johnson & Turner, 2003; Merriam, 2002; Maxwell, 1996; Teddlie & Tashakkori, 2003). Many strategies can help convince others that a study's data collection and analysis were credible. To this end, I employed a variety of techniques. First, I took copious notes about the exact procedures and steps I carried out during qualitative analysis. Second, triangulation or multiple sources of data (survey, video footage, simulated recall and semi-structured interview transcripts, field notes) were used to develop a holistic and plausible explanation of the data (Merriam, 2002). This technique added to the validity of the study as I relied on multiple forms of evidence rather than a single incident or data point in the study. Specifically, I committed myself to a systematic process when applying the *a priori* and open coding procedures. This process yielded a reliable convergence of findings from different data sources. Third, I employed member checks to verify accuracy of participants' transcripts (Maxwell, 1996). I asked participants to review a copy of their transcribed interview via email correspondence. Specifically, participants were asked to check for accuracy and make any recommendations for changes to accurately reflect their experience. Fourth, I employed a technique known as "bracheting" during both interviewing processes to avoid my personal biases (Merriam, 2002). I have taught for 10 years. I am a Nationally Board certified teacher. I have mentored many novice teachers. I generally do look at teachers' practice in an effort to help them. I made every attempt to control my assumptions or predispositions about the teacher, the context, the lesson, or the use of technology when interacting/interviewing with the participant. Bracheting helped me to not make judgments about what was good or bad, right or wrong, outdated or modern in the teachers' practices. Finally, thick-rich descriptions of the data were included in Chapter Four of this study (Merriam, 2002). Specifically, I provided copious descriptions of the teachers' settings, interactions, experiences, and actions during data collection so that readers might have the feeling that they have experienced, or could experience, the events being described. This level of vivid detail contributes to credibility and trustworthiness of this study's findings.

Ethical and Political Considerations

All data collection and analysis techniques render some ethical dilemmas. For example, observations and interviews can bring about risks and benefits for the participant. Participants may feel that their privacy has been invaded, become embarrassed, or reveal more than they intended. On the other hand, teachers may enjoy sharing their successes, deepening their self-knowledge, and/or engaging in more reflective practices.

All participants' information from this study was kept strictly confidential. All raw data was collected securely and stored in my password-protected computer. All identifiable information was saved separately from the raw data. Audiotape and videotape files will be destroyed at the end of this study. No reference will be made in oral or written reports that could link participants to the study. Pseudonyms were used when referring to all participants.

In terms of political considerations, the audience for this research looms large. The audience could range from the general public, policy makers, funding sources, or other practitioners. Research in education should always aim at moving the knowledge base of the field forward. Research is supposed to contribute to theory and practice, but only if it is appropriately written and disseminated to the right audience. Many guidelines are available in helping researchers navigate these considerations, however, the duty to conduct an ethical study lies within the researcher. I made myself be keenly aware of ethical issues bound to my research processes and I scrutinized all of my actions in light of these considerations.

Methodology Summary

According to Ivankova, Creswell and Stick (2006) "the complexity of the mixed-methods design calls for a visual presentation of the study procedures to ensure better conceptual understanding of such designs by both researchers and intended audiences" (p.17). Figure 3.1 shows the sequence of the research activities, the data collection and analysis procedures, and the products or outcomes for each of the planned stages in the *mixed methods exploratory sequential design* used in this study. The figure also shows the connecting points between the quantitative and qualitative phases, where quantitative analysis aided in participant pool formation for the subsequent qualitative phase. The term QUALITATIVE is capitalized to indicate the priority of the qualitative phase.

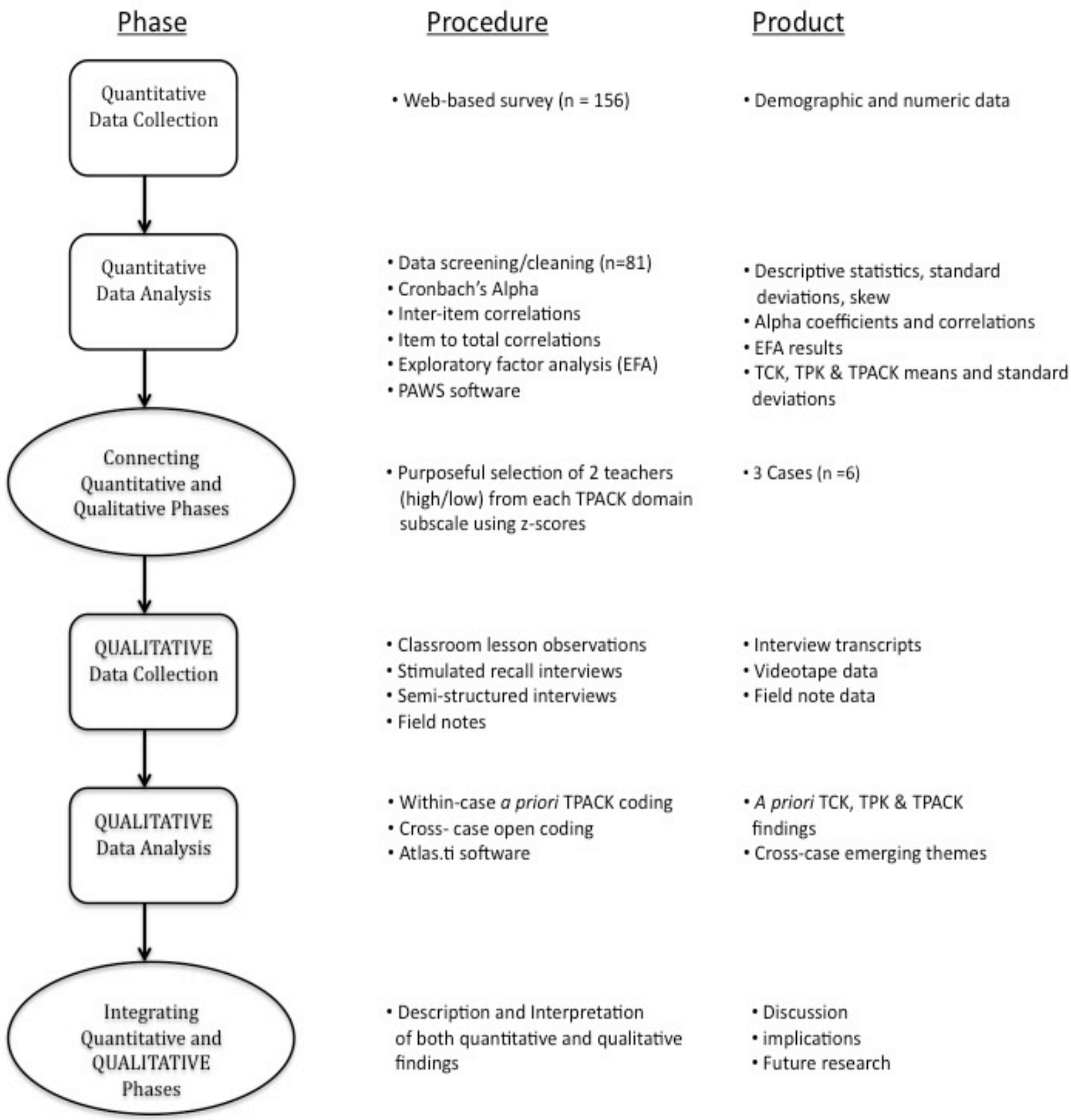

Figure 3.1. Visual model of mixed methods explanatory sequential design, participant selection model. Adapted from "Using Mixed-Methods Sequential Explanatory Design: From Theory to Practice" by N. Ivankova, J. Creswell and S. Stick, *Field Methods*, *18*(3), p. 3-20. Copyright by the 2006 Sage Publications.

CHAPTER FOUR: FINDINGS

This study was designed to better understand veteran teachers' professional knowledge and experiences while leveraging technology in 1:1 computing settings to support and enhance student learning. This study focused on three emerging constructs in a 21st century teachers' professional knowledge: technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK). This chapter presents the findings from my attempts to answer the research questions guiding this study:

1. How do revisions made to the *Survey of Teachers' Knowledge of Teaching and Technology* impact its reliability and validity for use with secondary teachers?
2. What are the self-reported levels of secondary veteran teachers' technological pedagogical content knowledge (TCK, TPK, and TPACK) practicing in 1:1 settings?
3. How are veteran teachers' technological pedagogical content knowledge (TCK, TPK, and TPACK) reflected in their instructional practices implemented in 1:1 settings?

I organized this chapter into three main sections. In the first section, I have provided the statistical results for the quantitative phase of the study including the following areas: (a) initial data cleaning and demographics, (b) examination of items from the adjusted *Teachers' Knowledge of Teaching and Technology Survey*, and (c) teachers' self reported levels of TCK, TPK, and TPACK. In the second section, I describe the results of the connecting phase of this study. In the third section, I have reported the qualitative results from *a priori* and open-ended coding as follows: (a) within-case findings and (b) cross-case findings.

Quantitative Phase Results

A total of 91 veteran secondary teachers practicing in schools from the North Carolina Learning Technology Learning Initiative (NCLTI) completed the adapted *Teachers' Knowledge of Teaching and Technology Survey*. These teachers had eight or more years of service and were teaching 6th through 12th grade. The NCLTI is comprised of schools that have 1:1 computing programs. The first 14 items on the survey gathered demographical and professional experience information. The final 32 items asked teachers to rate the extent to which they agree or disagree with statements in relation to their practices when using technology for teaching and learning. The survey employed the following five point Likert scale: (1) strongly disagree; (2) disagree; (3) neither agree nor disagree; (4) agree; and (5) strongly agree. The survey contains seven sub-scales: Pedagogical Knowledge (PK), Content Knowledge (CK), Technology Knowledge (TK), Technological Content Knowledge (TCK), Technology Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPACK). Each of the sub-scale items were content specific (e.g., I can teach lessons that appropriately combine science, technologies and teaching approaches) and/or content general (e.g., I can choose technologies that enhance the content for a lesson). I combined content specific items from the original survey with two additional items that I had created to form new content specific item subsets within the PCK and TCK subscales.

Initial Date Cleaning and Demographics

6 of the 91 respondents had missing data in their responses to the survey; therefore, these data were removed from the sample. This resulted in a total of 85 completed responses. Next, I transformed continuous data into z-scores using PASW (Predictive Analytics SoftWare) in order to examine these variables' distribution. Z-score transformation changes the central location of the distribution and the average variability of the distribution; it does not change the skewness or kurtosis (Agresti & Finlay, 1997). Z-scores provide a useful initial screening process for detecting outliers (Osborne & Overbay, 2004). I took note that four of the respondents raw scores resulted in z-scores that were approaching or over the suggested guideline of $z \pm 3.00$. Specifically, two respondents' responses for years of service (YOS) (independent variable) had z-scores of 3.07 and 2.82. Two other respondents' responses for technological pedagogical knowledge (TPACK) (dependent variable) had z-scores of -3.38 and -4.07. According to Clark and Watson (1995), subscales with extremely unbalanced distributions can produce highly unstable correlation results. In other words, retaining these data would significantly impact subsequent analysis of the data to adequately answer research questions one and two as stated at the beginning of this chapter. Table 4.1 represents the removal of those four respondents' responses and the effects upon distributional properties of continuous variables collected from participants.

Table 4.1

The Effects of Removal of Cases with Outliers on Continuous Variables Distribution

	Initial N	Cleaned N	Initial SD	Cleaned SD	Initial Variance	Cleaned Variance	Initial Skew	Cleaned Skew
YOS	85	81	8.05	7.31	64.81	53.40	1.70	.87
PK	85	81	.55	.42	.30	.18	-2.56	.30
TK	85	81	.78	.68	.59	.47	-.49	-.10
TPK	85	81	.67	.56	.45	.32	-1.03	-.03
CK	85	81	.64	.53	.41	.28	-1.75	-.24
PCK	85	81	.58	.47	.34	.22	-1.75	.44
TCK	85	81	.78	.71	.61	.51	-.92	-.59
TPACK	85	81	.72	.59	.52	.35	-1.22	-.20

All of the cleaned variables' skew were near or approaching 0, and therefore were normally distributed. However, the YOS skew of .87 was still large. As seen in Figure 4.1, a visual inspection of the histogram indicated a relative normal distribution.

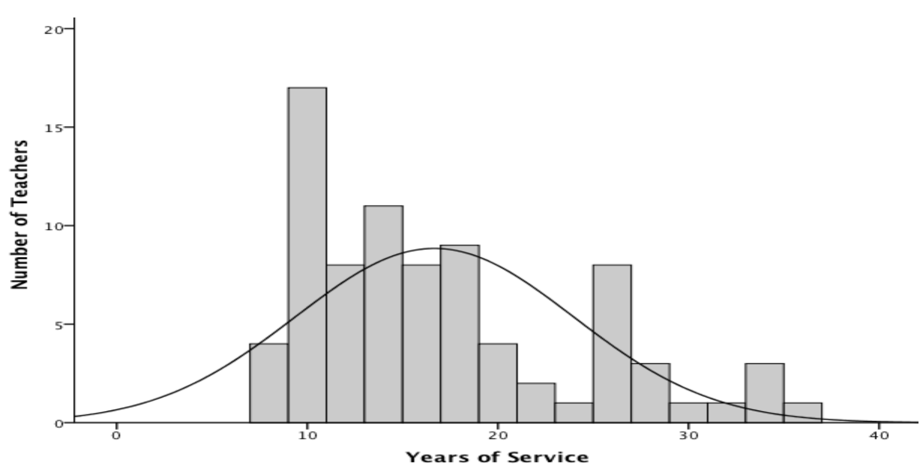

Figure 4.1. Histogram of teacher participants' years of service (n = 81).

In an effort to provide an overview of the final sample (n=81) used for this study, I have included Table 4.2 to present the results from demographic data (discrete variables).

Table 4.2

Demographic Characteristics of Cleaned Sample (n = 81)

Demographic Item	n	% of sample
I am a:		
Male	26	32.1%
Female	55	67.9%
I identify myself as:		
American Indian/Alaska Native	1	1.2%
Asian	0	0.0%
Black/African American	6	7.4%
Native Hawaiian/Pacific Islander	0	0.0%
White	73	90.1%
Hispanic/Latino	1	1.2%
Multiracial	0	0.0%
Other	0	0.0%
I teach in a:		
Middle School	17	21.0%
High School	64	79.0%
Are you currently a National Professional Board Certified Teacher?		
Yes	25	30.9%
No	56	69.1%

Table 4.2 continued.

Demographic Item	n	% of sample
What is your highest level of education?		
Undergraduate	45	55.6%
Masters	32	39.5%
Doctorate	4	4.9%
Which content area do you teach?		
English	33	40.7%
Math	18	22.2%
Social Studies	12	14.8%
Science	18	22.2%

This sample was generally representative of teachers practicing in the state of North Carolina. The most current data from the North Carolina Department of Public Instruction's Education Statistics Access System (ESAS) indicated that the ethnic makeup of teachers practicing in 2008 teachers was as follows: less than 1% Indian and Asian; 2% Hispanic, 23% Black; and 74% White. This study's sample included teachers practicing in schools in the North Carolina Technology Learning Initiative (NCLTI). NCLTI schools are primarily located in North Carolina's eastern and western counties so the more ethnically diverse central counties were not represented. This may explain some of the variance in White and Black teacher representation in this study. In terms of gender, this sample is very similar to 2008 ESAS statewide statistics where teachers in North Carolina were 79% female and 21% male. In 2009-2010, 73% of teachers held a bachelor's degree, 26% of teachers held a master's degree and 0.2% of teachers held a doctorate degree (North Carolina Department of Public Instruction*,* 2010). The current sample had a slightly higher percentage of teachers holding post-baccalaureate professional degrees.

Examination of the Adapted Teachers' Knowledge of Teaching and Technology Survey

Schmidt et al. (2009) asserted that their survey**,** *Teachers' Knowledge of Teaching and Technology Survey*, is a reliable measure of PK-6 preservice teachers' TPACK (see Chapter Two). They also suggested that separate factors for self-assessment in PCK and TCK in the content areas of mathematics, science, social studies, and English should be created for use with secondary teachers. As such, I added two additional items based on the language patterns of current items in the survey and definitions of PCK and TCK found in the literature. For PCK, the additional items are (a) I can select effective teaching approaches to illustrate difficult concepts within my content area and (b) I can select effective teaching approaches that reflect my student's prior knowledge. For TCK, the additional items are (a) I know about technologies that can deepen my content area knowledge and (b) I know about technologies that I can use to represent concepts within my content area. The current content specific items in the survey in combination with these additional questions formed the new content specific subsets of items in the subscales for PCK and TCK. Four content specific questions were removed from the TPACK subscale leaving four questions in the subscale from the original survey. In the following sections, I have provided initial evidence that subscale items in the adapted survey have internal consistency to answer my first research question: How do revisions made to the *Survey of Teachers' Knowledge of Teaching and Technology* impact its reliability and validity for use with secondary teachers? The use of reliability indices to establish the homogeneity of a scale is fraught with controversy. Specifically, internal consistency is only an indication of the degree to which the items that make up a scale are inter-correlated; whereas *homogeneity* denotes whether the subscale items measure a single underlying factor or construct (Clark & Watson, 1995). That is, internal consistency is a necessary, but not a sufficient condition for determining homogeneity among the subscale items in a survey. Yet, internal consistency estimates are not completely worthless: they can reveal valuable information about the proportion of error variance in subscales in a survey (1995). As such, I conducted statistical analysis to demonstrate the adapted *Teachers' Knowledge of Teaching and Technology Survey*'s subscale items possessed a sufficient level of reliability.

Internal consistency. The Chronbach's alpha analysis procedure was used in determining the internal consistency of adapted survey's subscales. The subscales of PK, TK, TPK, CK, PCK, TCK, TPACK had coefficients alphas of .85, .79, .81, .66, .85, .80 and .86 respectively. Clark and Watson (1995) recommend coefficient alphas of at least .80 as indicators of internal consistency for subscales. Most of all subscales on the adapted survey have alphas that met this mark. However, the alphas for the TK and CK subscale provoked me to consider eliminating weaker items or writing additional items for these subscales, as necessary, to increase internal consistency in future iterations of this adapted survey.

Inter-item correlations. Next, I explored inter-item correlations found in all seven subscales. According to Clark and Watson (1995), the average inter-item correlation is a more sensitive measurement than coefficient alpha; specifically, the mean inter-item correlation values of .15 to .50 or from .40 to .50 for narrowly defined constructs are acceptable measures of a single construct. The mean inter-item correlations for the PK, TK, TPK, CK, PCK, TCK, TPACK subscales were .48, .34, .51, .38, .64, .56 and .60, respectively. The lower means for the TK and CK subscale are consistent with the weak alphas previously reported.

Item-to-total correlations. I carried out an item-total correlation analysis to check whether any item was not consistent with the rest of the sub-scale. The ranges for the subscales in the adapted survey are shown in Table 4.3.

Table 4.3.

Item-to-Total Correlations Ranges for Adapted Survey's Subscales

Subscale	Range
PK	.54 to .79
TK	-.11 to .73
TPK	.55 to 67
CK	.34 to 56
PCK	.70 to 71
TCK	.50 to 78
TPACK	.54 to .76

The TK item yielding -.11, generally indicates a major red flag. De Vaus (2002) suggested that correlation values "less than .30 are considered weak for item-analysis purposes" (p. 184). This means that the item may have been highly ambiguous or confusing to participants.

As a result, I noted that some changes to this item might be required. However, according to Costello and Osborne (2005) a subscale with fewer than three items is generally weak and unstable. Moving forward in working on the adapted survey, more TK items need to be written.

Exploratory factor analysis. I originally proposed to investigate the internal structure of the adapted *Teachers' Knowledge of Teaching and Technology Survey* via an exploratory factor analysis (EFA) using principal axis factoring and an oblique rotation. My goal was to identify how many factors the adjusted survey would yield as well as the consistency of the additional items in the PCK and TCK subscales.

An EFA is a multifaceted process with few absolute guidelines. Several "debates" about the parameters for an adequate ratio, number of participants to the items in an instrument, can be found in the literature. Many early recommendations focused on the importance of sample size. Guilford (1954) recommended a minimum sample size of 200 for consistent factor retrieval. Comrey (1973) posited that researchers obtain sample sizes larger than 500 to generate significant and reliable results. Other researchers made ratio recommendations ranging from 3:1–6:1 to 20:1 (as cited in De Winter, Dodou, Wieringa, 2009). Other researchers have advocated obtaining the highest cases-per-variable ratio possible in order to "minimize the chance of over fitting the data" (2009, p. 148). A popular and prevalent rule-of-thumb used for EFA analysis is having a 10:1 ratio for sample size to number of items (Costello & Osborne, 2005; Thompson, 2004). I had every expectation my sample would have this ratio, however my sample size fell well short of the widely accepted guideline of a 10:1 ratio.

I still felt it was important to attempt to investigate the internal structure of the adapted *Teachers' Knowledge of Teaching and Technology Survey*, so I ran an EFA analysis using principal axis factoring and an oblique rotation. The EFA extracted six viable factors. Upon visual inspection of the Scree plot, I discovered only three factors were of relative importance. A sharp drop in the plot, after the third factor, indicated the subsequent factors were ignorable; the magnitude of variance accounted for by the remaining three factors was insignificant. This was a radically different result than reported by Schmidt et al. (2009) where the seven factors, PK, TK, TPK, CK, PCK, TCK, TPACK, were present. The first three factors Eigen values accounted for 56.65% of the total variance. At this point, I examined the factor loadings, looking for patterns in the loading correlations to find a best-fit model that relates to how the literature defines PK, TK, TPK, CK, PCK, TCK, and TPACK subscales. A rule of thumb to assess whether estimated factor loadings are practically and meaningfully significant is to look for factor loadings of .30 or .40 (Sass, 2010). I used this guideline to help identify patterns of factor loadings among items. I also screened for redundant or double loading items. Of the 32 items, five items had double loadings on Factor 1 and Factor 2 and one item had double loadings on Factor 3. In addition, fifteen items had loadings of .60 or higher on Factor 1. In frustration, I turned to the literature for help. DeWinter, Dodou and Wieringa (2009) conducted a series of small *N* data simulations and found that for most research objectives a large sample size is required to produced useful EFA results (i.e., low to medium loadings among subscales in a survey with a large number of factors). That is when factors are not well defined or their numbers are large, a small sample size EFA may not yield valid or reliable solutions. Comfrey and Lee (1992) suggested, "the greater number of variables with substantial loadings, the easier it is to isolate what the factor represents" (p.241). As these research examples would suggest, my EFA results offered no viable psychometric approach to divide the items into separate factors. I rejected the EFA results as evidence to assess the emerging validity and reliability of the adapted *Teachers' Knowledge of Teaching and Technology Survey* due to a small sample size and small number of items in each subscale of the adapted survey.

However, Cortina (1993) affirms that "judgment of adequacy" can be given to a survey in light of the context of the research (p. 101) when factor loadings are not acceptable. The alpha coefficients and item correlation results were strong for the adapted *Teachers' Knowledge of Teaching and Technology Survey*. The focus of this study centered only on TCK, TPK, and TPACK and their subscales yielded alphas of .81, .80 and .86, respectively. Consequently, I decided that moving forward with the study was warranted. I believe this study's unique research questions, design, and data properties would yield illuminating findings that add to the emerging literature about the TPACK theoretical framework; particularly when attempting to understand veteran teachers' disparate professional knowledge when using technology during instruction in the 1:1 classroom. Therefore, I used the quantitative results, as they were, to answer the second research question guiding this study: What are the self-reported levels of secondary veteran teachers' technological pedagogical content knowledge (TCK, TPK, and TPACK) in 1:1 settings? In Table 4.4 are participants' mean, standard deviations and skew for participants' TCK, TPK, and TPACK subscale scores from adapted *Teachers' Knowledge of Teaching and Technology Survey.*

Table 4.4

Mean, standard deviations and skew for participants' TCK, TPK, and TPACK subscale scores (n =81)

	M^{*}	*SD*	Skew
TCK	3.89	0.71	- 0.59
TPK	3.98	0.56	- 0.03
TPACK	3.98	0.50	- 0.20

[*] Note: means are based on the following five point Likert scale: (1) strongly disagree; (2) disagree; (3) neither agree nor disagree; (4) agree; and (5) strongly agree.

Connecting Phase Results

The quantitative results from phase one of this mixed methods study helped to distinguish teachers' self-perceptions of their TPACK. As a reminder to the reader, I transformed the individual participants' raw scores for TCK, TPK, and TPACK to z-scores to locate results that differed from the normal distributions for each subscale. Pools of potential participants were established using z-scores that were one standard deviation above or below the mean for each subscale. Across all three subscales, many of the same participants could be selected. As such, any entry point for pool formation could eliminate possible participants that were previously selected for a different construct. To identify the most illuminating case for each high and low case for TCK, TPK, and TPACK, the entry point for pool formation was determined by the subscale that yielded the largest z-scores above +/- 1.00. As such, pool formation began with the TCK subscale where the largest z-score of -2.39 was found.

The "low" TCK participant pool was formed using the five largest negative z-scores ranging from -2.39 to -1.53 and the "high" pool was formed using five participants who all had the highest z-score of 1.49. I then used the next biggest z-scores from the TPACK subscale, -1.64 to -1.29 and 1.15 to 1.46, to form the "low" and "high" pool of five participants each, while eliminating any duplicates already taken in the TCK pools. Finally, the "low" (-1.39 to -1.02) and "high" pool (all 1.21) for TPK was formed with participants not already included in the TCK and TPACK pools. A total of six teachers, one from each pool, agreed to participate in the qualitative phase of this study.

Qualitative Results

The process of analyzing and coding the qualitative data was described in Chapter Three. This section presents the qualitative results regarding the third research question: How are veteran teachers' technological pedagogical content knowledge (TCK, TPK, and TPACK) reflected in their instructional practices implemented in 1:1 settings? These findings are offered in two sections: a) within-case findings; and b) cross-case findings.

Within-case Findings

The TPACK (2006) framework is extensive and complex therefore the findings were challenging to present. I have reported the findings from each case using the same format. First, an overview of the specific TPACK construct along with the analytic components and markers for that specific construct are briefly described. Second, a table of analytic components and the markers corresponding to that construct of the TPACK framework is provided. Third, a profile of each teacher including their teaching context and a brief overview of their observed lesson. Fourth, findings for each construct of TPACK are presented, with the findings supported by data—interviews, video, or field notes from each teachers' lesson. Fifth and finally, I offer a summation of the findings for each case.

"TCK" case findings. TCK characterizes teachers' knowledge about the technology-content interaction that occurs independently of their pedagogy (Cox, 2009; Mishra & Koehler, 2006). Teachers with TCK demonstrate a capacity for effectively choosing and leveraging the appropriate technology within their content area teaching and learning process. An overview of the TCK analytic components and markers is provided in Table 4.5.

Table 4.5

TCK Analytic Components and Markers

TPACK Domain	**Analytic Component**	**Markers**
TCK	*Using technologies best suited for addressing content learning:* teachers understand the affordances and constrains the types of content ideas that can be taught with technology (Koehler & Mishra, 2008)	*Declarative*: technology may be used help students indentify (not necessarily simulate) with the targeted content. *Procedural:* technology to help students think about how to use the content knowledge *Schematic:* technology to guide students in understanding why and when they might use their new content related knowledge *Strategic:* technology that affords their students the ability to synthesize their new knowledge to either create a product or a performance that demonstrates their specific content learning (Niess, 2008)

Table 4.5 continued.

TPACK Domain	Analytic Component	Markers
TCK	*Using technologies that best simulate or represent content domain knowledge*	Content was represented via video
		Content was represented in audio
		Content was represented by images (LCD, SmartBoard, class website, etc.)
		Content was represented directly by Internet/ Web2.0 tool or application

In the first phase of data analysis, data were interpreted, not through the search for emergent themes, but against three sub-constructs of the TPACK framework. It can be extremely difficult to observe teachers' knowledge of the relationship between technologies and content (i.e., TCK) because this knowledge is situated in their own conscious. So to the extent possible, evidence of TCK in the transcript data was triangulated with video and field note data. The teachers in my TCK case were Sheila and Rachael.

Self-reported high "TCK" teacher: Sheila. Shelia taught 7th grade language arts at a rural school on a traditional calendar. She held a Master's of Education in Middle Grades Education/Language Arts and a National Board Certification. She had 13 years of teaching experience; she spent 10 years teaching 6th grade language arts at a different middle school located in a nearby county. In my field notes, I documented that Shelia stated that her current county's switch to 1:1 laptop computing in the Fall semester of 2009, starting with the 7th grade, had greatly influenced her move to this grade and school. Her current school, one of four middle schools in the local school district, was located at the foot of the Blue Ridge Mountains in northern North Carolina. Based on the most current public statistics, this school served approximately 650 students, 71% White, 24% Hispanics, 4% Black, in grades 6th through 8th and made Adequate Yearly Progress[1] (AYP) in 2009 (Education.com, 2010). In 2009, Sheila's school had 58% of students eligible for free or reduced price lunch programs[2]. In 2009, North Carolina had 33% of eligible students for free or reduced price lunch programs (2010). In 2007, the average percent of teachers with 10 years or more years experience was 78 % and was similar to the state average of 77 % (2010). 25% percent of teachers working in Shelia's school held a Masters degree or higher which equaled the state average (2010).

Shelia's school will loan a Dell Latitude 2100 laptop computer to students upon compliance with the following:

- Student Orientation/Training session;
- Parent/Guardian Orientation/Meeting session;
- Payment of $27 insurance fee;
- A signed Student/Parent Laptop Agreement.

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[1] Under No Child Left Behind, a school makes Adequate Yearly Progress (AYP) if it achieves the minimum levels of improvement determined by the state of North Carolina in terms of student performance and other accountability measures.

[2] Eligibility for the National School Lunch Program is based on family income levels.

The laptop agreement along with copies of *1:1 Laptop Most Frequently Asked Q&A* and *1:1 Laptop Initiative Handbook* can be downloaded in both English and Spanish at the school's website. Shelia reported that a technology facilitator was available to her team three hours a week. She indicated these professional experiences exposed her to "technology for teaching, not for the sake of technology, alone." She described leadership support for technology use at her school as "moderate." Sheila was the very first participant to respond to my Phase 2 recruitment email. Via email correspondence, we arranged an observation of her 45-minute first period class on October 18, 2010. She claimed to "use technology every day" and described herself as a "proficient" user of technology and "much more skilled" than her peers.

Sheila's classroom was approximately 30′ x 30′ with white and blue walls. Seating was arranged in a backward U-shaped design (i.e., chairs were placed in front of tables so students had to turn away from their laptops to see the Smart Board, near which, Shelia did most of her teaching). My observation began when students first came into the classroom. She greeted each student as they entered. The students began to, in Sheila's words, "SWARM." Sheila further explained that SWARM is "when they first come in, they already know to power up and get ready for class, and then they hibernate when it's time to get started with the lesson." Her class had 11 boys and 14 girls.

Shelia's 7th grade language arts lesson required students to use higher-level thinking skills when identifying, analyzing and evaluating mood and tone when reading a selected text. Previously, students were studying subjective and objective writing. Sheila wanted her students to pay more attention to how mood and tone can shape these writing genres. The lesson began with Shelia conducting a review of tone and mood. On the Smart Board, she brought up her class wiki on PBWorks where she had linked a Glog that housed the period’s entire lesson.

The TCK *using technologies best suited for addressing content learning* analytic component helped me discover data where Shelia specifically leveraged technologies for 7th grade language arts learning. In the lesson, Shelia used the Website as shown in Figure 4.2 to read aloud a legend entitled “Girl at the Underpass,” once without tone and once with tone.

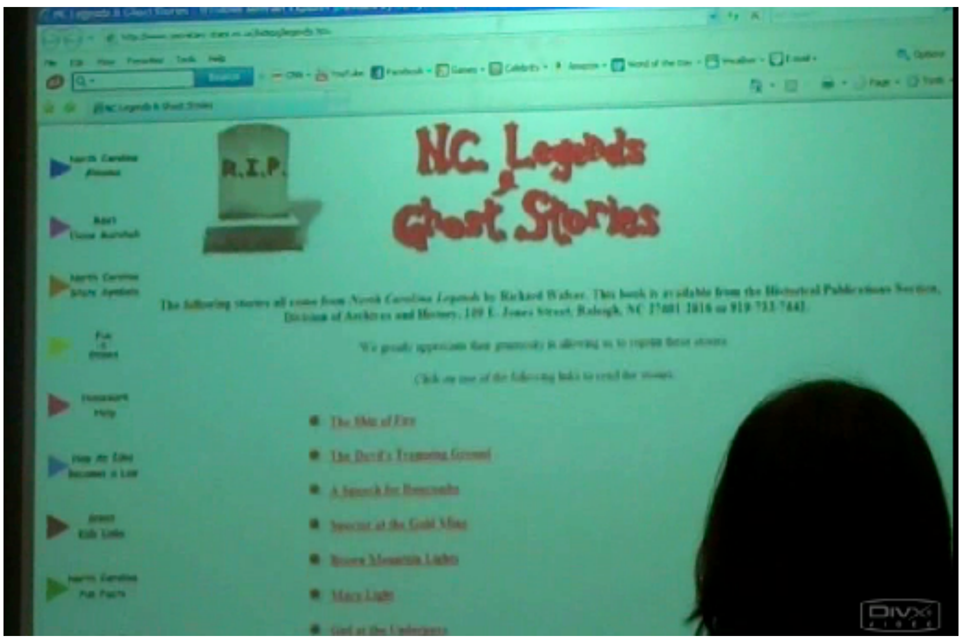

Figure 4.2. Legend website from video.

She displayed the legend as shown in Figure 4.3, and she explained why she made this choice:

> I wanted them [students] to focus only on hearing me read the words on the screen. So they had to try a little harder to, especially the first time I read it, figure out what the tone was. I chose to leave it [the legend] just as it was instead of creating

something else to put on the Glog. It's just black-on-white, and they're going to see that they need to be able to figure out mood and tone with black-on-white or printed text.

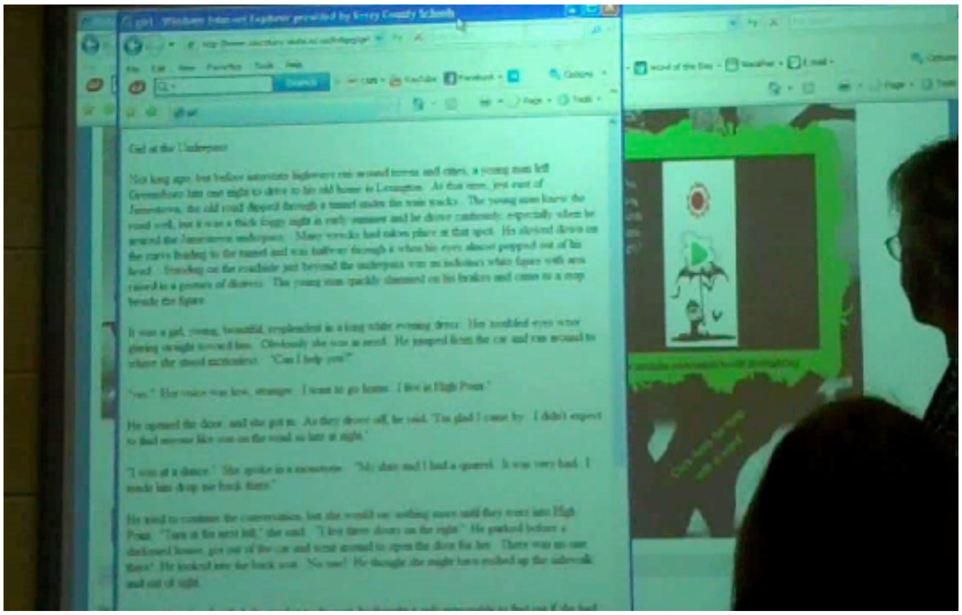

Figure 4.3. "Girl at the Under bridge" legend as used in the lesson from video.

Shelia's use of technology helped her students better identify tone and so was at the *declarative* level. This decision showed her grasp on considering the purpose of the technology in the context of her discipline.

The word "resplendent" was used in the legend. After probing the students, Shelia discovered her students did not understand its meaning. She quickly opened a Web 2.0 tool called VisuWords as shown in Figure 4.4.

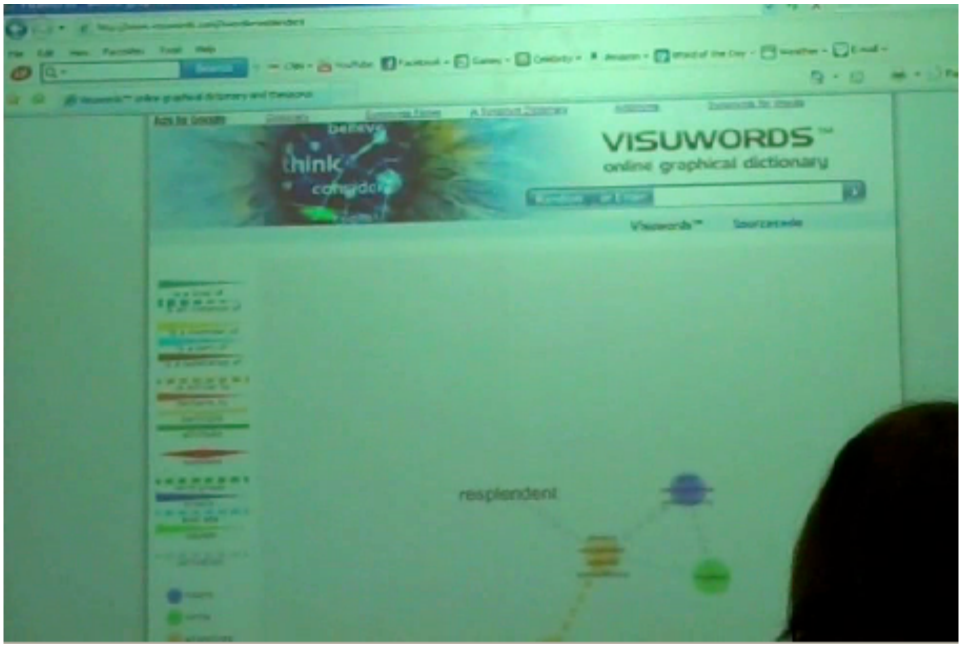

Figure 4.4. VisuWords display for "resplendent" from video.

Shelia explained that "because a word can have different meanings depending on the context, students can get all the meanings the word can have, and then they can apply it to our story." This quote represents the marker of *procedural* as it demonstrated Shelia's understanding of how VisuWords helped her students think about how to use their vocabulary knowledge while reading. She commented, "I can put VisuWords on the screen, full-screen, here's the word, and show all of the different meanings, and they use that, they don't pick open the dictionary after they finish reading. That's finding information right there and putting it in the context immediately." I remarked in my field notes that students were shaking their heads up and down indicating a better understanding after they reviewed the word and then listened to Shelia re-read the sentence with "resplendent."

Shelia's use of VisuWords also represented the analytic component of *using technologies that best simulate or represent content domain knowledge.* Shelia shared:

> I have used some other thesaurus sites, but they weren’t all-inclusive. When I found VisuWords, it was like, the heavens opened and the moon and the stars aligned. It allows my students to see synonyms and antonyms. They can see all the different relationships the word can have. I love VisuWords because it shows all kinds of different word associations, instead of just only the definition.

This comment exposed Shelia’s astuteness in selecting an appropriate Web 2.0 technology that can be utilized and transform vocabulary understanding through representation.

During the lesson, Shelia showed a video that used color and music to invoke mood. An example is in Figure 4.5.

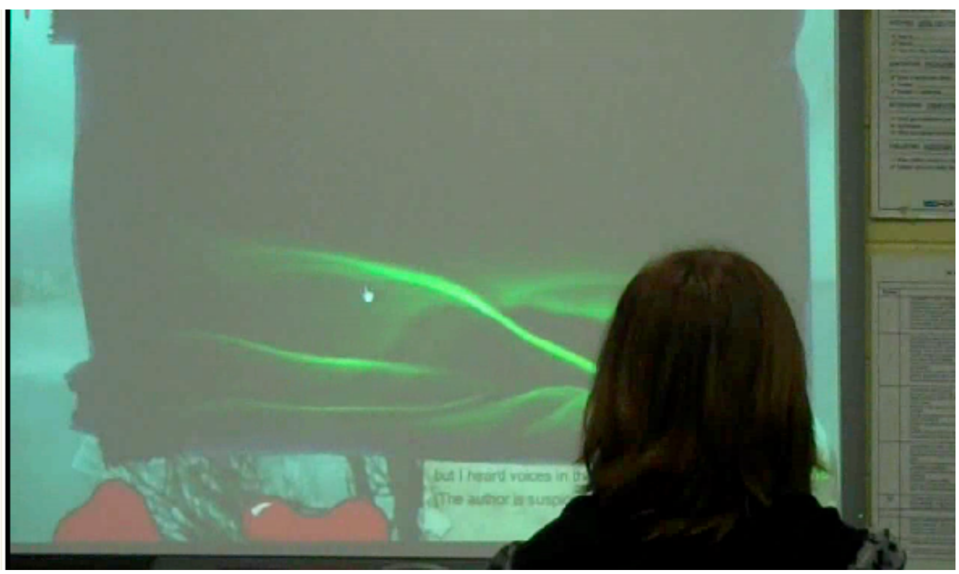

Figure 4.5. Mood video using colors and music.

Shelia commented:

> Before I taught this lesson I thought, “Now how am I going to get kids to understand tone and mood?” I can explain it to them all day long, but if they don’t experience it, they’re not going to understand it. So there are no words on the video to tell them

> what their mood is supposed to be. They have to construct their own meaning for that, they have to find that within their own experience, they have to connect it to something.

Her thinking here demonstrated how she deeply considered how technology could assist her students to identify with mood and thus was at the *declarative* level.

When reflecting on her use of this video to support content learning at the *schematic* level, Shelia stated:

> It's just color. It doesn't even have a real meaning. It's just the color and the sound together. I wanted to see what mood they [students] actually could come up with that worked for them. I wanted them to understand that when they are reading some vampire book, like *Twilight*, or something like that, that this is when you think about mood. That's why I used the video.

Immediately after the video, she discussed how she thought about mood when she read *Twilight* and related it back to the video. In my field notes, I recorded how students started seat dancing to the more "upbeat" music and stopped when it changed to "darker" music. In addition, I noted that students started telling each other what they thought the mood was in the book they were currently reading (i.e., independent reading). The above quote revealed Sheila's pure knowledge about what technology does for helping her guide her students in understanding of why and when they might use their new content related knowledge about mood. Additionally, Shelia's clearly used this video to *simulate* mood.

Shelia demonstrated her TCK at the strategic level when she discussed features on her Glog as shown in figure 4.6:

> I gave them a short list of mood words, because in the past I've seen them use the same exact word for tone and mood. I wanted to push them away from that, because it's not always the same. Now when they have another writing assignment that involves tone and mood, they'll ask me, 'Can I go back to that tone Glogster?'

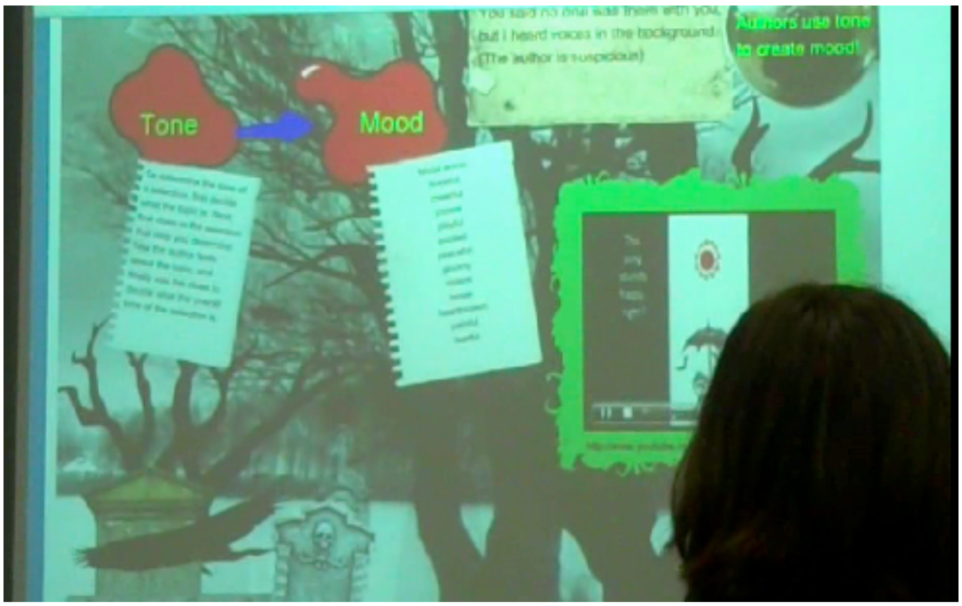

Figure 4.6. Tone and mood content on the Glog.

This quote from Shelia illustrated two important ideas about TCK. First, she knew how to use a technological program or tool to *do* her discipline. Second, she recognized the multiple possibilities and potential of the technology – she used Glogster in the current lesson, but also understood how this technology can be used to aid in students' synthesis of their new learning in a future writing activity.

When discussing her Glog, as seen Figure 4.7, Shelia exposed, more fully, why she purposefully made it the way she did to simulate or represent mood and tone.

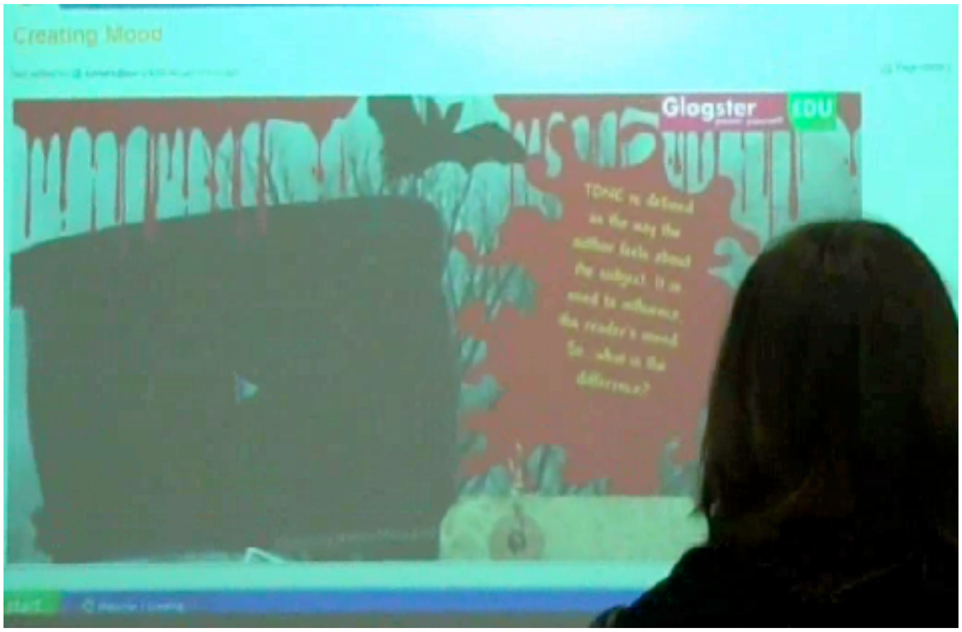

Figure 4.7. Shelia's Glog for the lesson.

During the SRI, Shelia stated:

> Even the tone of the Glogster page itself was already set up for them. They could look at the blood dripping, the creepy tree in the background. Just the scene itself had visual tone. Did you hear when they [students] were looking at it, they were like, "Oh!" So hopefully it has a little bit more meaning for them.

Indeed, I certainly documented the "oohs" and "ahhs" the students exhorted as soon as the Glog appeared on the Smart Board in my field notes. Shelia's above assertion makes plain that she leveraged this technology based on the imperatives of a particular content area skill, in this case mood and tone.

Self-reported "low" TCK teacher: Rachael. Rachael taught 7th grade language arts in a small, rural community in northern North Carolina, one of four middle schools in the local school district. She held a Bachelor's in Nutrition, Master of Arts in teaching and National

Board certification. She had 18 years of teaching experience; all teaching language arts in various middle school grades. Based on the most current statistics, this public school served approximately 500 students, 89% White, 7% Hispanics, 3% Black, in grades 6th through 8$^{th.}$ and met AYP in 2009 (Education.com, 2010). In 2009, Rachael's school had 41% of students eligible for free or reduced price lunch programs as compared to the North Carolina average of 33% (2010). In 2007, the average percent of teachers with 10 or more years experience was 88% compared with the state average of 77 %. Thirty-two percent of teachers working in Rachael's school held a Masters degree or higher which was greater than the state average of 25% (2010).

Rachael did teach in the same district as Sheila, but at a different school. So the 1:1 policies and materials are the same as described for Sheila (see above). Rachael reported that a technology facilitator worked personally with her about an hour a week. She indicated that these professional experiences targeted the "presentation of a technology/tool only." She described that the type of leadership support for technology use at her school as "moderate." Via email correspondence, we arranged an observation of her 45-minute first period on November 15, 2011.

Rachael's classroom was approximately 30′ x 50′ and outfitted with a Smart Board. Student seating was arranged in six groups of four fixed chair desks. My observation began when students first came into the classroom and began, without direction, to retrieve and turn on their laptops. The class was comprised of 11 girls and 11 boys.

Rachael's 7th grade language arts lesson was a review of vocabulary, characterization and plot associated with *Rikki-Tikki-Tavi*, a story from Kipling's *The Jungle Book,* in preparation for a test the next day. The lesson began when she brought up her class wiki on PBWorks by way of the SmartBoard where she had linked several SmartNoteBooks that housed the activities for the lesson. The students first completed the activities on their own laptops, and then, when called upon, they completed the activity on the SmartBoard.

The *using technologies best suited for addressing content learning* analytic component was valuable in discovering data that aligned with this aspect of Rachael's TCK. The lesson started with an anagram activity using a SmartNotebook as shown in Figure 4.8. Directly on the SmartBoard, Rachael wrote the vowels and consonants that were to be used to come up with the right word after she provided a definition. After the first word, she provided a rule for the letters in that word to be used in conjunction with a new definition for the next word. For example, the first definition given was "opposite of warm" so the word was "cool" which was then recorded on the SmartBoard. Next she stated the rule "change one letter and rearrange" and provided the definition of the next word "doing something on your own"; the next word was "solo."

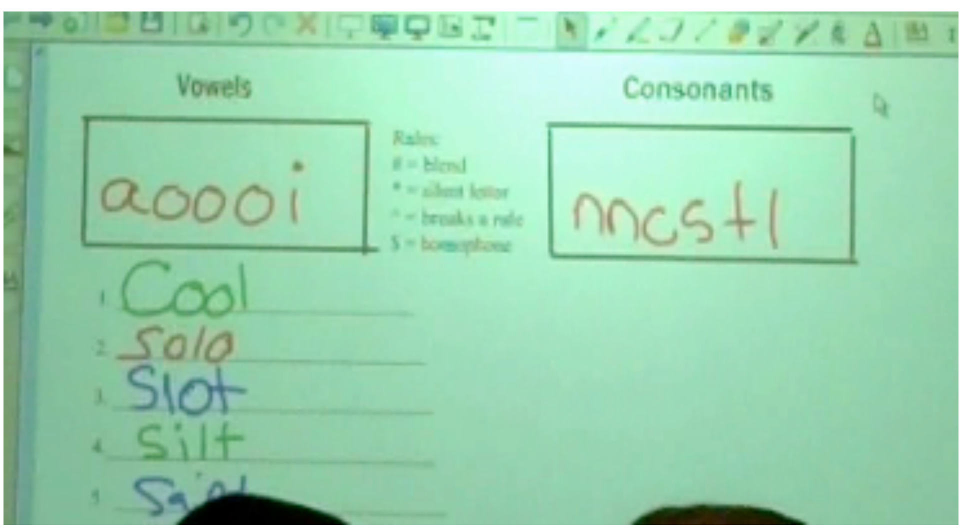

Figure 4.8. Anagram activity from video.

She explained why she made this choice:

> I go to Smart Notebook and I made that anagram chart, and then I link it. It helps to ease the mode of conveying information, like with the anagrams, it's quick, it's fast, and that's what I like, that it makes them think about language.

Rachael's use of technology helped her students better understand selected vocabulary words at the *declarative* level. This decision indicated her grasp of specifically considering the purpose of the technology in the context of her discipline.

Next, Rachael opened a Smart Notebook page where students could move words around to place them under the correct character from *Rikki-Tiki-Tavi* as shown in Figure 4.9.

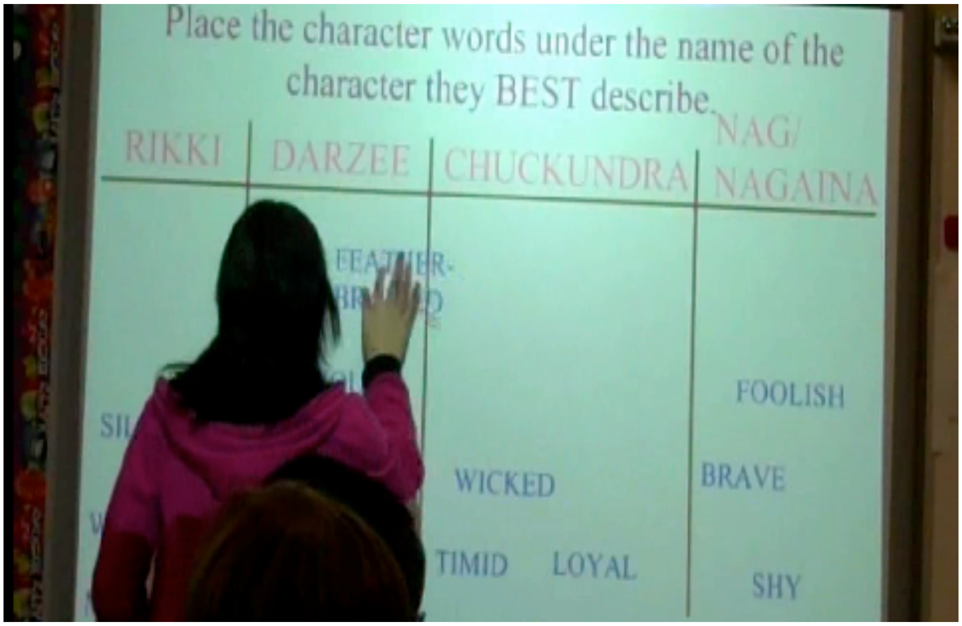

Figure 4.9. Character trait activity from video.

Rachael offered:

> When the students had to choose the character trait that best describes the characters in *Rikki-Tikki-Tavi*. They had to get what the question is and they don't always get the

> choices. I tried my best to include words in the Notebook they knew, like words like wimpy. I wanted to make sure that they did see words they don't have a real clue about. I wanted to bring in some of those words like vindictive and malicious to see if they would figure those out.

While students were at the SmartBoard moving the words to the correct character, Rachael asked them to justify their choice. Each student specifically referred to an event from *Rikki-Tikki-Tavi*. I noted that other students were also piping up with different events that also justified their choice. Rachael's rationale represented her TCK at the *schematic* level as it demonstrated her understanding of how an activity using technology better helped her students think about when and why they would apply their comprehension of the story to correctly determine the appropriate character trait.

As shown in Figure 4.10, Rachael pulled up a *Rikki-Tikki-Tavi*. review on a PowerPoint that she recently put into a Smart Notebook to show students that they could now access it.

Figure 4.10. Rikki-Tikki-Tavi review from video.

She commented on this part of the lesson as follows:

> The whole PowerPoint is now online that we did last week. I did the whole PowerPoint around my content…what I wanted them to get. They can come back and pull it up to review what is important in *Rikki-Tikki-Tavi* as they study for the test.

This quote from Rachael illustrated her TCK at the *strategic* level, as she clearly understood how to use the technology in aiding her students’ synthesis of their new learning as they prepare for the test.

Rachael had students complete an activity on direct and indirect characterization as shown in Figure 4.11.

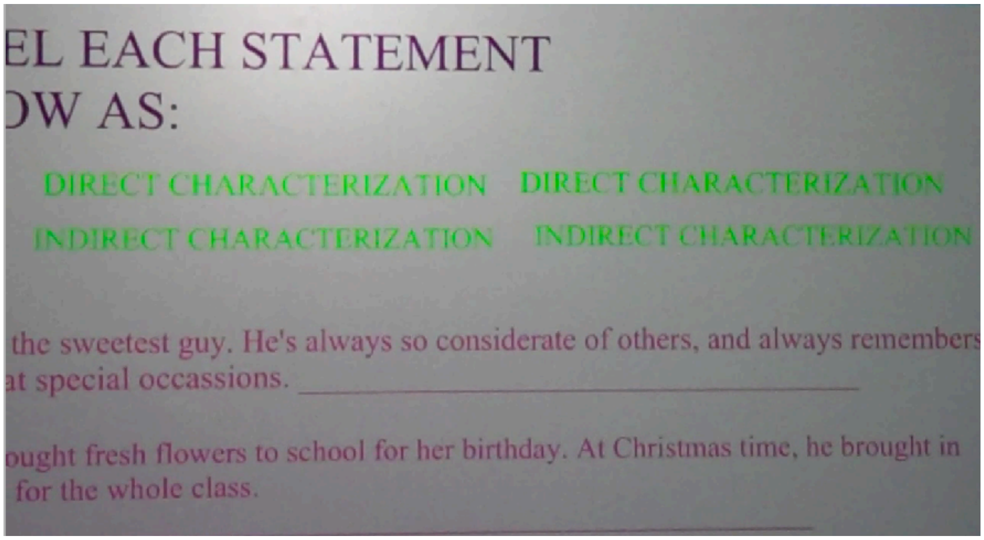

Figure 4.11. Direct and indirect characterization activity from video.

During her SRI, Rachael explained:

> The kids pretty much knew what was, but it is one of those kind of gray areas, that is, exactly how do they use it. It’s kind of like they know it but they don’t know quite what they know. Anyhow, I made some examples on the Notebook. It could help the kids understand it better. I was hoping they would be like “Oh, yeah!” by seeing it.

Her rationale represented the marker of *procedural* in her TCK. She understood how the technology could help her students think about *how* to use their understanding of direct and indirect characterization.

Rachael’s use of a Smart Notebook for an activity about the *Rikki-Tikki-Tavi* plot, as seen in figure 4.12, represented the analytic component of *using technologies that best simulate or represent content domain knowledge.*

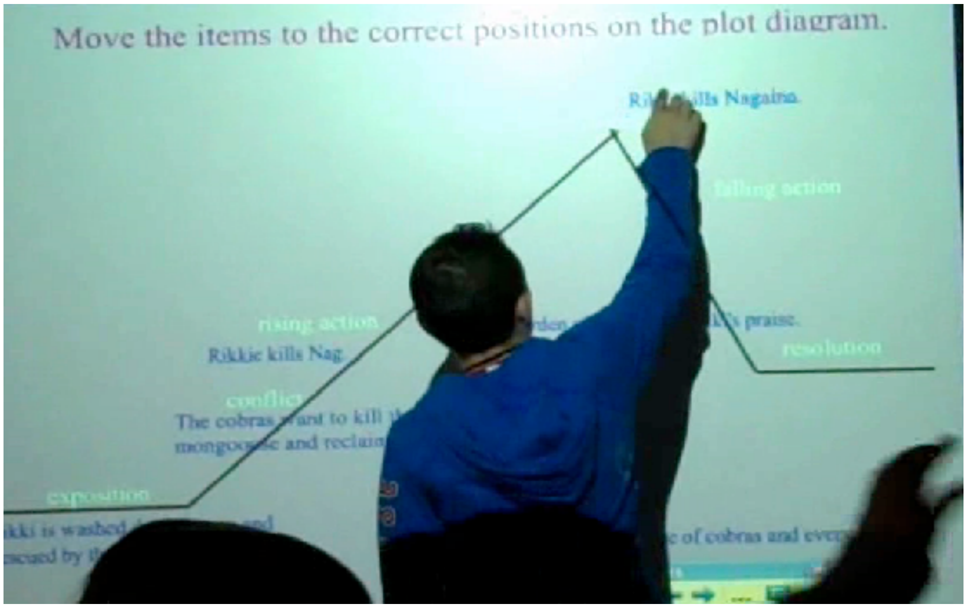

Figure 4.12. Plot activity on SmartBoard from video.

She commented during her SRI:

> We've been doing plot for a number of weeks, looking at plot structure and development. If I just pulled an example off the Internet, a lot of plot diagrams are equilateral, and I don't like that. That's not how story structure is. It's not equilateral. Well, I knew I could draw the lines and make the diagram how I wanted it on Smart [Notebook] and just pull up the diagram.

This declaration made plain that Rachael purposely leveraged this technology based on a specific aspect of her discipline, in this case plot.

TCK case summary. Both Shelia and Rachael demonstrated vibrant, active, and diverse examples of the ways in which their TCK guided them in making instructional decisions when facilitating a technology-infused lesson. SRI, video and field note data revealed that both teachers confidently made strategic technology choices they felt best (a) supported their students' content learning (Rachael, for example, noted her Smart Notebook characterization activity helped her students "understand it better"); and (b) represented or simulated their content (Sheila, for instance, created her entire Glog as a total "mood and tone" simulation). The declarative, procedural, schematic and strategic markers surfaced largely in the teachers' videos and interview comments. These findings may shed light on the effectiveness of these markers as a theoretical lens when examining how teachers' tacit content knowledge impacts their practice with technology (Niess, 2008), which will be examined further in Chapter Five.

In an effort to synthesize the findings in the TCK case, I have developed Figure 4.13 that highlights similarities and differences between Sheila and Rachael's practice.

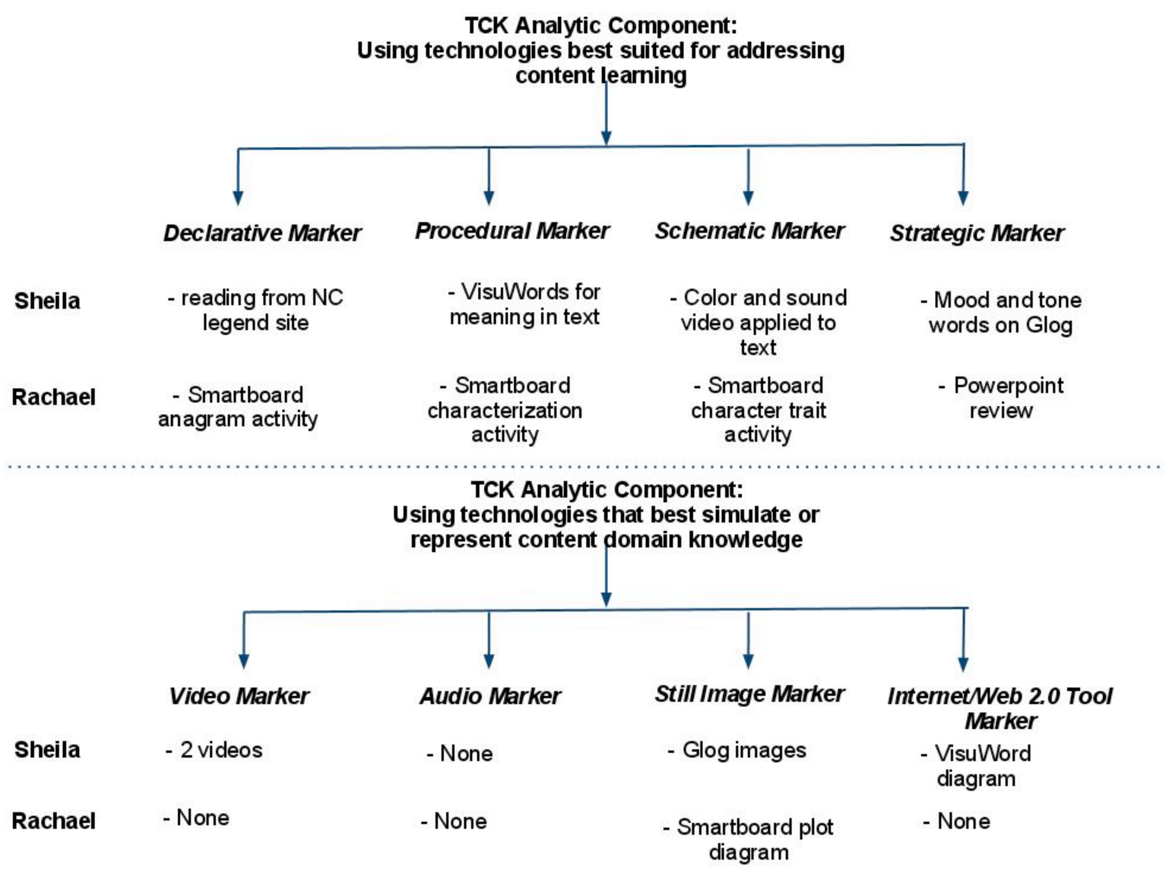

Figure 4.13. TCK case findings by analytic components and markers.

"TPK" case findings. TPK conceptualizes the knowledge about how technologies may be used to meet teachers' pedagogical aim(s) in the classroom (Koehler & Mishra, 2008). I have provided a brief overview of the TCK analytic components and markers in Table 4.6.

Table 4.6

TPK Analytic Components and Markers

TPACK Domain	**Analytic Component**	**Markers**
TPK	*Using technology as part of a pedagogical strategy*	General pedagogical aim (Hughes, 2008) Repurposing: "develop skills to look beyond the immediate technology and "reconfigure it" for their own pedagogical purposes" (Koehler & Mishra, 2008, p. 17) Considering student learning: "learning changes when particular technologies are used" (Koehler & Mishra, 2008, p. 16)

The teachers in my TPK case were Yasmine and Mike.

Self-reported "high" TPK teacher: Yasmine. Yasmine taught Biology, Honors Biology and Library Science in a large public high school located in the county seat of a metropolitan area in eastern North Carolina. She held a Bachelor's degree in teaching and had 11 years of teaching experience; all teaching various middle school grades. Her school, one of three high schools in the local school district, served 836 students, 51% Black 38% White, 11% Hispanics in grades 9^{th} through 12^{th} and *did not make* AYP in 2009 (Education.com, 2010). In 2009, Yasmine's school had 56% of students eligible for free or reduced price lunch programs as compared to the North Carolina average of 33%. In 2007, the average percent of teachers with 10 years or more years experience was 46% compared with the state average of 77 % (2010). Nineteen percent of teachers working in Yasmine's school held a Masters degree or higher which was less than the state average of 25% (2010).

Yasmine's school adopted 1:1 laptop computing in the Fall semester of 2003, starting with the 7th grade. Yasmine's school will loan a Mac Book laptop to students upon compliance with the following:

- Payment of $70 insurance fee;
- A signed *Hold Harmless Agreement, Acceptable Use Policy* and *Responsible Use and Liability Contract*.

The above insurance information and agreement along with copies of a *Handbook for Parents and Basic Features of Your Mac Book* could be downloaded in English at the school's website. Yasmine reported that a technology facilitator was available to help three days a week. She reported that the type of leadership support for technology use at her school was "moderate." Via email correspondence, we arranged a date and time for her observation on November 5, 2010.

Yasmine's classroom was approximately 40′ x 50′ and outfitted with sinks and lab areas. Student desks were in rows, facing each on either side of an aisle down the middle of the classroom. In front of her whiteboard, she had a cart with a laptop and projector. My observation began when students first came into the classroom and began, without direction, to turn on their Mac Books. The class was comprised of 15 girls and 10 boys.

Yasmine's 10th grade Biology lesson centered on North Carolina's standard course of study competency goal 3.03. Specifically, the lesson served as a review of the following:

- Dominant, recessive and intermediate traits associated with genetic disorders.
- Sex-linked traits associated with genetic disorders.
- Pedigrees associated with genetic disorders.
- Punnett squares associated with genetic disorders.

The three markers for the analytic component of TCK, *using technology as part of a pedagogical strategy,* were (1) general pedagogical aim, (2) repurposing and (3) consideration of student learning.

The first marker helped me discover how Yasmine leveraged technology to carry out characteristic teaching practices. The lesson began when she had her students pull up a Thinking Map on their laptops to record the information she wrote on the whiteboard as seen in Figure 4.14.

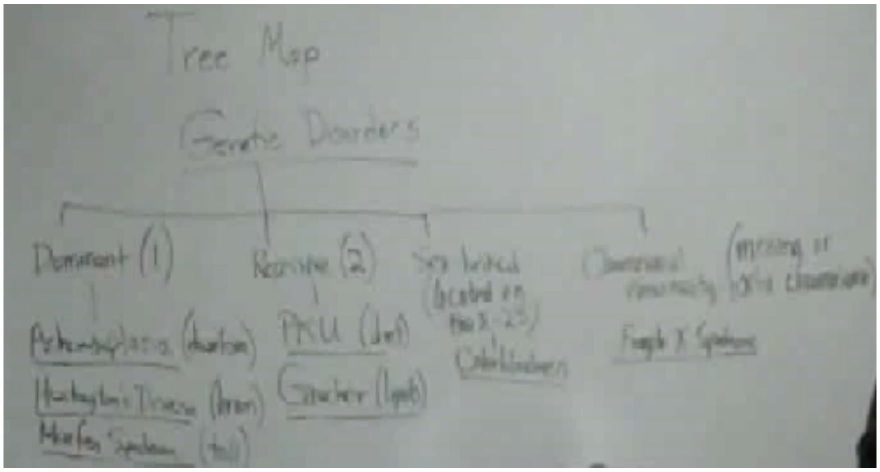

Figure 4.14. Thinking Map information from video.

Yasmine stated:

> There are several reasons I chose to do this tree map. Number one it classified the genetic disorders. Basically I had already taught the lesson, so now I had just wanted to organize their thoughts and bring everything together, so they would know what diseases were dominant, what diseases were recessive, what diseases were sex-linked, and which diseases were chromosome abnormalities. This tool is useful because they can go back to it and study.

Yasmine used the Thinking Map to help her students take notes, a typical teaching practice. She added, "I didn't have to sit there and ask, 'Who needs a piece of paper? Who needs a pencil?' I could move at a much faster pace." General pedagogy includes consideration of the pacing in a lesson.

Conducting assessments is a traditional pedagogical practice. Yasmine directed her students to complete a 15-item assessment in ClassScape. She explained her use of this technology as follows:

> ClassScape, it's just a test bank, developed by the people who created the EOCs. It has about a 1000 biology questions. There are 200 or so just for Goal 3. I just went through and looked at all of 3.03. I chose 15 questions then I saved it for use today.

In addition she highlighted how the technology helped her carry out another common teaching skill, she commented:

> Most students want results immediately, they don't want to wait a week. If they take a paper test; I try to get my kids stuff back graded quickly, but a lot of times that doesn't happen. With this [ClassScape] they don't have to wait. As soon as they push "enter," they had their score. You could see the kids…they were calling me over, saying, "I got 15/15.

Indeed, I had noted her students' spontaneous exclamations of success along with other students who said, "Oh, how did I miss that one?" Yasmine's TPK was directly reflected in her recognition of how ClassScape aids in providing immediate feedback to her students' academic performance. When reflecting further about this part of the lesson, Yasmine said, "I noticed that most kids missed the pedigree questions; I will make sure that I reiterate that on Monday." Yasmine planned to use assessment results to drive remediation, a standard aspect of good pedagogy.

At one point in the lesson, Yasmine reminded students to check E-Chalk to ensure they knew when their papers were due. She explained that, "E-Chalk is our school website. Instead of putting everything on the board for them, I use E-chalk to post what their assignments are, when their next test is, when their papers are due and when their quizzes are scheduled." Ensuring that students are aware of what is required of them is a customary teaching practice. Yasmine took full advantage of E-Chalk to meet this pedagogical aim.

The marker "considering student learning" revealed ways in which Yasmine was aware of how technology has impacted her students, and successfully engaged them in academic activities. For example, as seen in Figure 4.15, students had to create a Keynote presentation to demonstrate their understanding of a genetic disorder they were assigned to research.

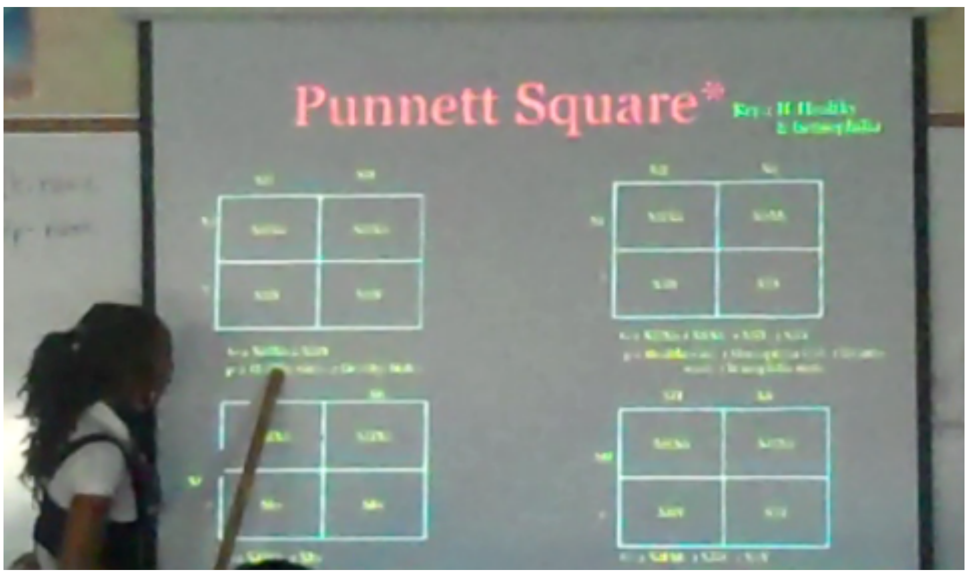

Figure 4.15. Example of student's Keynote presentation on Hemophilia from video.

During her SRI, Yasmine elucidated:

> I chose Keynote because basically it gives them a chance to do something more exciting than just assigning a one-page summary on a genetic disorder. That would not have been as engaging or as interesting. They were able to go in front of the class and teach someone else about that one topic. They were the "master" of one topic.

> They had to create the pedigree charts and the Punnett squares. I think it tapped into many different parts of their brain, especially their creativity.

Yasmine clearly demonstrated her understanding of how her pedagogical choice of Keynote impacted her students' engagement level and learning in Biology.

Self-reported low "TPK" teacher: Mike. Mike taught 9^{th} and 10^{th} grade English at a public high school set within an historic community located in eastern North Carolina. He held a Bachelor's in Education and a National Board Certification. He had 13 years of teaching experience; all teaching English in various high schools in his district. His school, one of five high schools in the local school district, served approximately 750 students, 89% Black, 29% White, 6% Hispanic, in grades 9^{th} through 12^{th} and made AYP in 2009 (Education.com, 2010). Mike's school had 59% of students eligible for free or reduced price lunch programs as compared to the North Carolina average of 33% (2010). In 2007, the average percent of teachers with 10 years or more years experience was 71% compared with the state average of 77% (2010). 21% of teachers working in Mike's school held a Masters degree or higher which was slightly less than the state average of 25% (2010).

Mike's school made available Dell Latitude E5400 laptops to all 9^{th} through 12^{th} graders starting in the Spring semester of 2009. Mike's school will loan a laptop to students for use both at school and home upon compliance with the following:

- Laptop Care and Guidelines;
- Payment of $50 technology fee;
- A signed Student/Parent Laptop Agreement.

The agreement and guidelines along with copy of *Laptop FAQs* can be downloaded in English at the school's website. Mike reported that a technology facilitator was available to work personally with him about three hours a week. He indicated that his professional experiences targeted the "presentation of a technology/tool only." He described the type of leadership support for technology use at his school as "moderate." Via email correspondence, we arranged a date and time for his observation on November 12, 2010.

Mike's classroom was approximately 20′ x 30′ and stuffed full of boxes of T-shirts for a yearbook fundraiser. Student desks were in horizontal rows parallel to a whiteboard at the front of the room. He had a cart with a laptop and projector squeezed in between the student desks in the front row. The class was comprised of 5 girls and 9 boys. It is important to note that these students had not successfully passed the English I End of Course (EOC) competency as 9th graders and thus were enrolled in Mike's English I EOC Remediation course.

Student entered the classroom but did not retrieve their laptops. Mike's lesson was a review of the following grammar elements: punctuation, subject-verb agreement, sentence fragments, and run-on sentences.

The three markers for the analytic component of TCK, *using technology as part of a pedagogical strategy,* were (1) general pedagogical aim, (2) repurposing and (3) consideration of student learning. The TCK marker, *general pedagogical aim*, helped reveal how Mike used technology during his typical teaching practices.

The lesson began with students completing a Daily Oral Language (DOL) activity, as seen in Figure 4.16. On a paper handout, they corrected grammar and punctuation mistakes found in three sentences. Students did not have their laptops out during this activity.

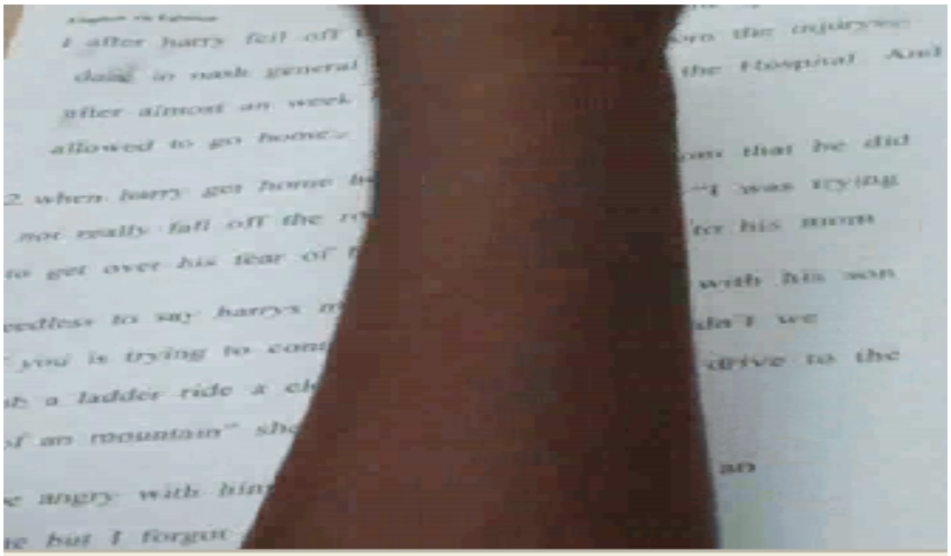

Figure 4.16. DOL handout from video.

Mike explained that “We have a benchmark on Monday, and the benchmark is on grammar. It [DOL activity] was prepping them for that benchmark.” Mike used the DOL activity to help his students review for a test, a usual teaching practice. He shared “the reason I started out with the DOL activity on paper is because I didn’t want the shuffling and whatnot that’s associated with students pulling out their laptops and getting them plugged.” Teachers’ classroom management is part of their general pedagogy.

As seen in Figure 4.17, students, after completing the sentences on their own, corrected the DOL sentences at the overhead project.

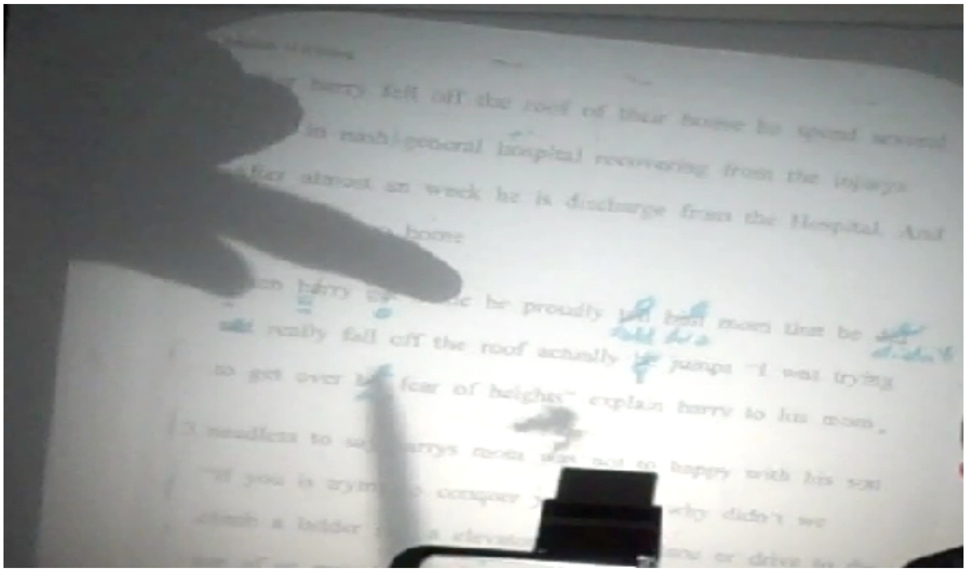

Figure 4.17. Student correcting DOL sentences on overhead from video.

During his SRI, Mike commented:

> The overhead has actually been a really useful tool for me over the years for things like modeling and showing student samples. I've experimented with the document camera, and that works okay, but sometimes the refocusing of the document camera can kind of interrupt what's going on. I know that the overhead is kind of "old-school," but it's so effective for just raw teacher/student interaction. Sometimes slapping a transparency up there is seamless. So it's something that I continue to use a lot. I haven't really found something to replace it with.

Albeit the overhead projector is not generally regarded as technology by 21st century standards, it technically is. Mike appropriately used the overhead to model correct punctuation and grammar for his students, a customary pedagogical practice.

As mentioned previously, using assessment during the act of teaching is a standard pedagogical practice. As shown in Figure 4.18, Mike asked his students to complete a series of benchmark reviews in Study Island.

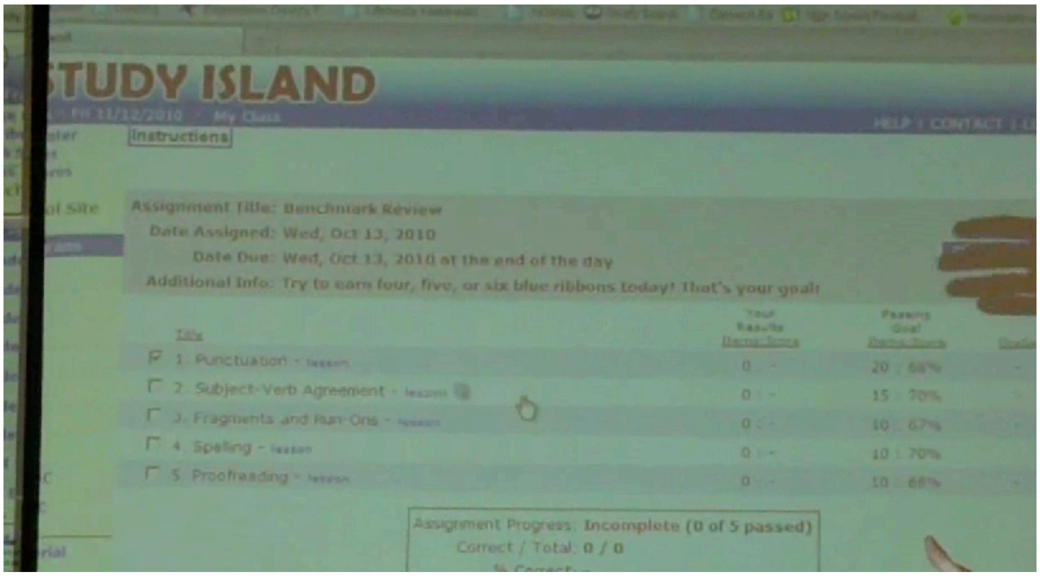

Figure 4.18. Example of Study Island from video.

He explained his use of this technology as follows:

> Study Island has objective-based lessons and assessment activities that are aligned with our standard course of study. So I'm able to identify specific objectives that I want to focus on. Like today, for example, the five grammar objectives in Study Island related to all the other activities they did today.

When reflecting further about this part of the lesson, Mike said:

> It is important to me that I know who knows what. Large-group discussion can give the illusion that the whole class knows why to capitalize something or where the comma goes or why this was a subject-verb agreement problem. You probably saw that there were a lot of questions during the Study Island time, a lot of kids raised

their hand asking me this or asking me that. That's exactly what I wanted. It gives me a chance for 1 on 1 intervention and feedback.

My field notes reflected Mike working with individual students to address their understanding of the skills and concepts assessed in the Study Island activity. Mike's TPK was directly reflected in his recognition of how Study Island aids him in providing direct and immediate feedback as well as opportunities for re-teaching grammar concepts.

The marker "considering student learning" helped to illuminate the ways Mike was aware of how technology impacted how his students' engagement and motivation when planning his instructional activities. For example, as seen in Figure 4.19, students are participating in a Jeopardy Game downloaded and modified by Mike.

Figure 4.19. Example of Mike's Jeopardy game from video.

During his SRI, Mike reflected:

> I do a PowerPoint with them three or four days a week related to grammar, and often they're skills-based, and most of them are things I made. I got the PowerPoint template off the Web so I can't claim credit for. I made the questions to go with it. I wanted to do something that was light and fun and kind of collaborative.

In depicting his understanding of how the use of technology can change student learning, Mike stated, "their engagement was really good, they were drawing off of each other in terms of engagement. My kids tend to be more visual learners anyway." Mike clearly demonstrated her understanding of how her pedagogical choice of using the Jeopardy game impacted his students' engagement level and was conducive to their learning style.

TPK case summary. Data collection in this case yielded detailed examples of how Yasmine and Mike's TPK was evidenced in their pedagogical strategies employed during their lessons. The three markers related to the TPK construct were (1) general pedagogical aim, (2) repurposing and (3) considering student learning. Existence of their TPK, as a general pedagogical aim, was evidenced by their explicit value of assessment via technology; the phrases "immediate feedback" and "bench marking" came up more than once in their interviews. Yasmine and Mike also described the ways in which they considered student learning when using technology. For example, in efforts to deepen their students' learning they both provided " more engaging" and "collaborative" activities supported by technology. Neither, Yasmine or Mike repurposed technology during their lesson: this topic of repurposing is examined further in Chapter Five. Figure 4.20 provides a graphic snapshot of the TPK case findings.

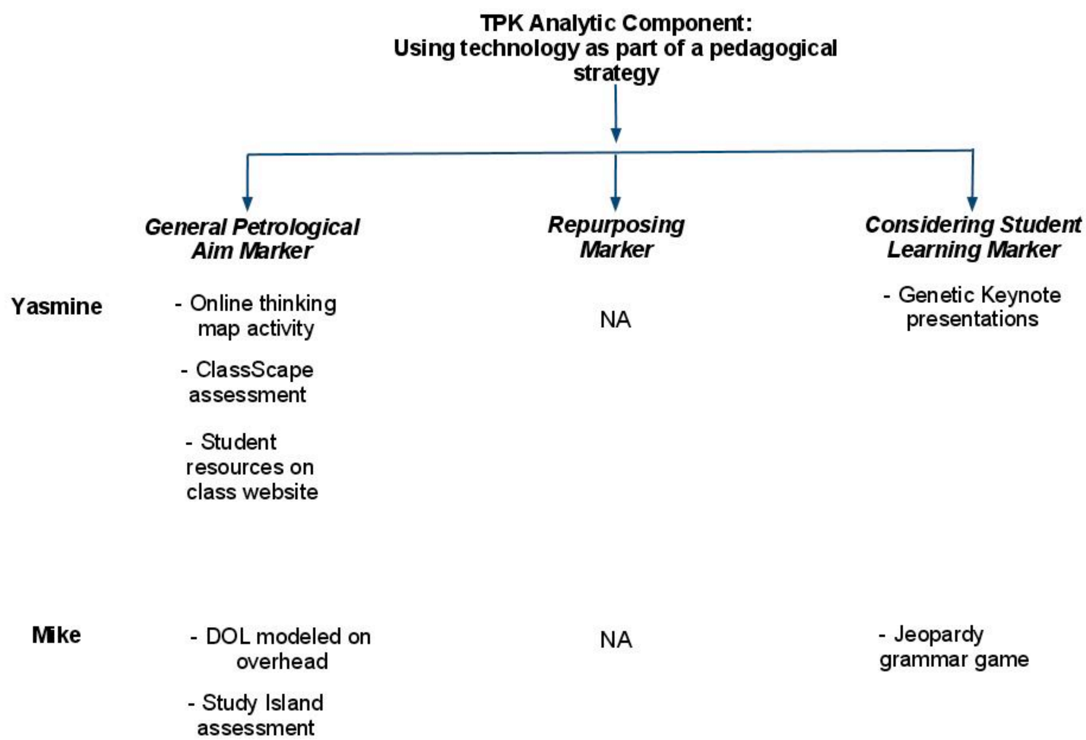

Figure 4.20. TPK case findings by analytic components and markers.

TPACK case findings. TPACK illustrates teachers' ability to engage in a transactional negotiation among their content, pedagogy, and technology knowledge domains (Mishra & Koehler, 2006). Teachers implement new skills and understandings when they combine these knowledge domains while teaching with technology.

Table 4.7

TPACK Analytic Component and Markers

TPACK Domain	**Analytic Component**
TPACK	*Using pedagogical techniques that constructively and continuously incorporate technologies to teach content: "*teaching successfully with technology requires continually creating, sustaining, maintaining and re-establishing a dynamic equilibrium between each component" (Koehler & Mishra, 2008, p. 20)

The TPACK case teachers were Liam and Sophie.

Self-reported "high" TPACK teacher: Liam. Liam taught AP Physics, Honors Physics and Honors Earth Science in a sizeable public high school situated in the county seat of metropolitan area in eastern North Carolina. He held a Bachelor's in teaching and had 11 years of teaching experience; all teaching various high school sciences. His school, one of three high schools in the local school district, served approximately 830 students, 51% Black 38% White, 11% Hispanics in grades 9th through 12th and *did not make* AYP in 2009 (Education.com, 2010). In 2009, Liam's school had 56% of students eligible for free or reduced price lunch programs as compared to the North Carolina average of 33%. In 2007, the average percent of teachers with 10 years or more years experience was 46% compared with the state average of 77 % (2010). Nineteen percent of teachers working in Liam's school held a Masters degree or higher which was less than the state average of 25% (2010).

Liam taught in the same school as Yasmine. So the 1:1 policies and materials are the same as described for Yasmine (see above). Liam reported that a technology facilitator was available to him three days a week. He described the type of leadership support for technology use at his school as "strong." Via email correspondence, we arranged a date and time for his observation on November 5, 2010.

Liam's 40′ x 40′ classroom was outfitted with sinks in lab areas. Student desks were in horizontal rows parallel to the chalkboard. In front of his chalkboard, he had a cart with a laptop and projector. Since this was an 11th grade AP Physics class, only 2 girls and 2 boys were in attendance. The students did use their laptops during the entire period. Liam's lesson centered around the Law of Conservation, specifically examining inelastic collisions through measuring velocity and height to determine Kinetic energy.

The analytic component, *using pedagogical techniques that constructively and continuously incorporate technologies to teach content,* of TPACK helped me discover how Liam leveraged technology to carry out characteristic teaching practices. The class began with an oral review of the previous night's homework problems that then quickly moved to the whole group collaborative effort. As seen in Figure 4.21, they began working out an inelastic collision problem on the board. The students did not have their laptops, but they were using calculators as seen in Figure 4.22.

Figure 4.21. Review of inelastic collision problem from video.

Figure 4.22. Students using calculators during lesson from video.

Liam explained:

> There's no other way to figure out why they [students] got the solution wrong or where they went wrong. She [one of the students] was off by a factor of 10. I don't

> want them to panic because they just forgot to take the square root of something or they forgot to convert. So that becomes less of an issue if they can use the calculator while we are doing the problem on the board. I want to demonstrate the physics, so the kids just have the calculators and do it all at once. It's the right tool. It's neat when we're doing a problem, sometimes I'll say, "Okay, this is where the physics is over, and now the rest is just math.

Liam was clearly paying particular attention to student learning and content while using technology, a hallmark of TPACK. This quote demonstrated Liam's knowledge of how a general pedagogical concern (student engagement) and technology (students using calculators) mingled with his transmission of a content-specific skill (determining Kinetic energy in the inelastic collision problem).

For the remainder of the lesson, students bounced two different balls (see Figure 4.23 and Figure 24) under motion detectors (see Figure 4.25) that sent data to an Xplorer GLX, a handheld portable graphing data logger (see Figure 4.26) to examine displacement of energy.

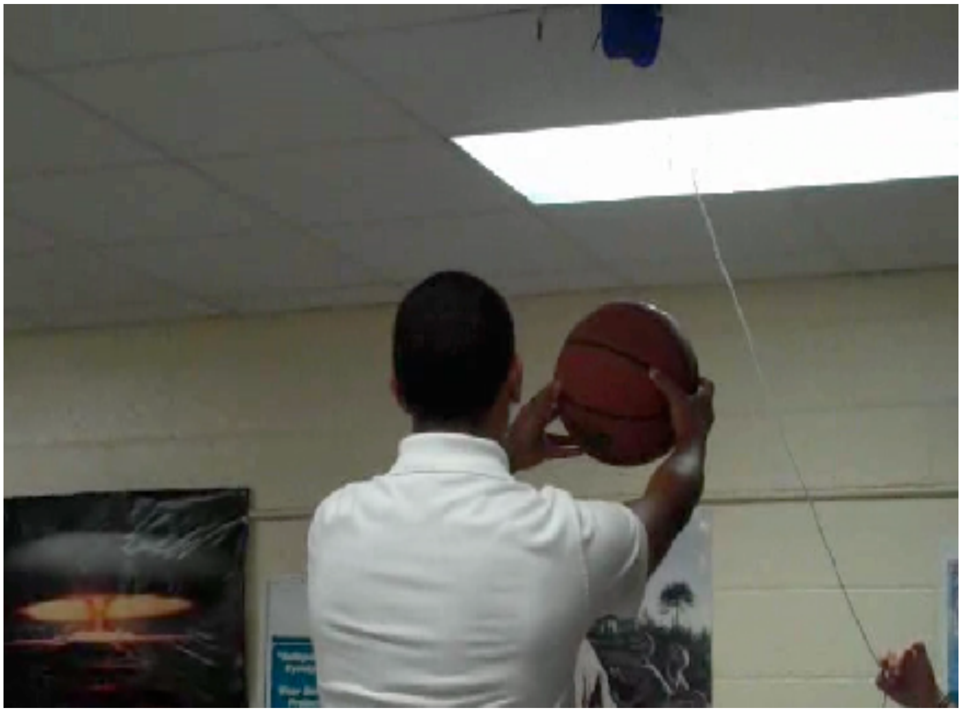

Figure 4.23. Student dropping a basketball during elastic collision lab from video.

Figure 4.24. Student dropping Magic Wizard ball during inelastic collision lab from video.

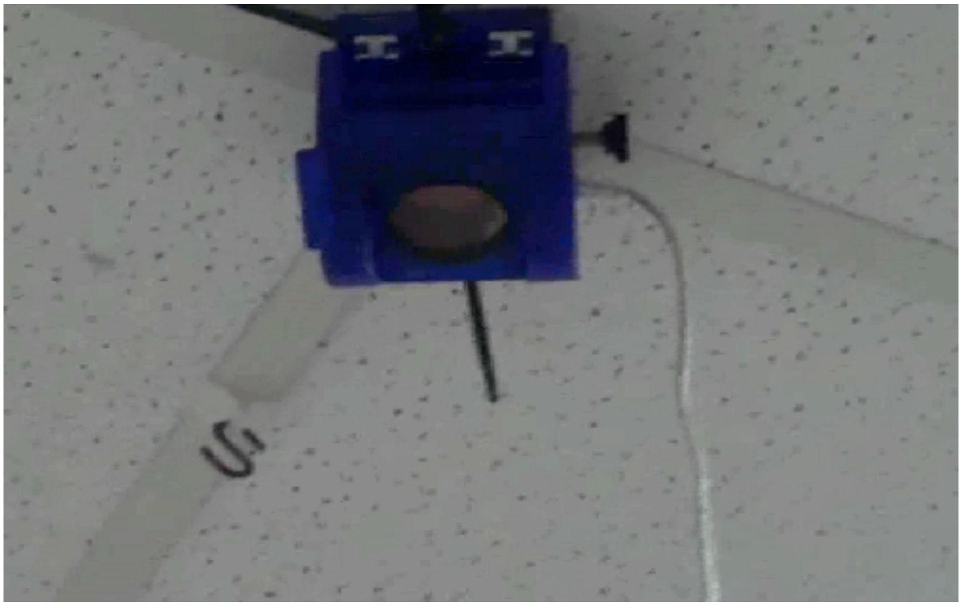

Figure 4.25. Motion detectors used in inelastic collision lab from video.

Figure 4.26. GLX handheld used inelastic collision lab from video.

Liam reflected:

> I love to use data-gathering stuff, like the ones that are hanging from the ceiling are sonic motion detectors. You can hook it to the handheld GLX lab pro to measure,

> depending on what data you're collecting, displacement, velocity, acceleration, and so on. The sensors record it [data] and then put it into the handheld unit. It's [technology] a very fluid stepping stone to help them [students] look at the real thing that's going on, which is the physics.

Liam was certainly aware of how the students' use of the motion sensors and the Xplorer GLX was an appropriate pedagogical strategy to better develop their knowledge of physics.

As seen in Figure 4.26, the GLX has a screen that students manipulated to further understand the data they had collected. Liam shared his thoughts about how this affordance of the GLX effectively further scaffolded his students' physics learning:

> So these [GLXs] have precision, you can set them, like to the ten-thousandths, it keeps track of milliseconds, and it auto-scales it and it gets all beautiful and pretty data. So it [GLX screen] has these bumps on the graph, and looking at the bumps, when talking about kinematics, they [students] would see, the top of the bump is flat, because for just a moment it's [ball] motionless, and with these curved paths, which is velocity. To get the percents, becomes very easy, they just move the cursor to the data points, it gives you your Xs and Ys, So it [the GLX screen] becomes just another cog in the wheel of the machinery that's helps them to understand the physics behind it.

After the students finished capturing their data, they plugged their GLXs directly into a printer and produced graphs like the one seen in Figure 4.27.

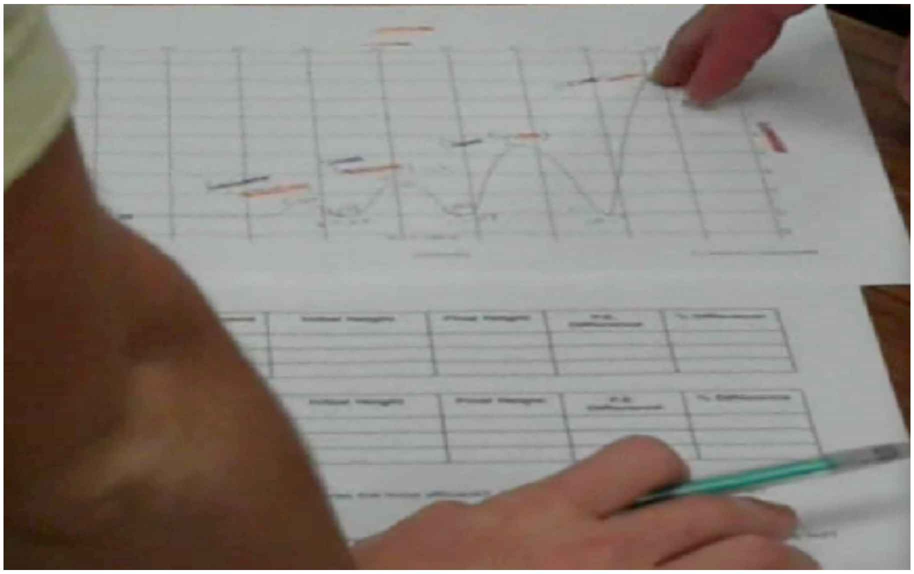

Figure 4.27. Graphs produced from GLX handhelds from video.

It is important to note that I deemed the graphs to be technology by association. That is, without the GLX handhelds, the students would not have had these graphs to complete the rest of their lab. Specifically, in Liam's SRI transcripts, I consider his reflections about the graphs as referring to technology. Liam explained:

> They [students] still need to know how to graph, they still need to know how to add and multiply and all of that good stuff, but if that's not your focus, and if you want to get to point D or E down the road, then it's alright if technology helps you skip past B or C, you know? They [students] started immediately putting values on it [graph]. They got invested in the process of looking at the data to see what the data has to tell them. Then they started correlating that data with the principles of physics.

This quote illustrates Liam's knowledge of how to coordinate technology, instructional activities, and content representations in the classroom to facilitate student learning that constituted his TPACK.

Self-reported "low" TPACK teacher: Sophie. Sophie taught 7th grade language arts and held a Master's of Education in Middle Grades Education/Language Arts and a National Board Certification. She had 10 years of teaching experience. Her school, one of four middle schools in the local school district, was located in a rural county in northern North Carolina. Based on the most current public statistics, this school served approximately 430 students, 86% White, 12% Hispanics, 2% Black, in grades 6th through 8th and made Adequate Yearly Progress (AYP) in 2010 (Education.com/, 2010). In 2009, Sophie's school had 50% of students eligible for free or reduced price lunch programs (2010). In 2007, 65% of the teachers had 10 years or more of experience. Thirty-eight percent of teachers working in Sophie's school held a Masters degree or higher which was slightly higher than the state average (2010).

Sophie's school will loan a Dell Latitude 2100 laptop computer to students upon compliance with the following:

- Student Orientation/Training session;
- Parent/Guardian Orientation/Meeting session;
- Payment of $27 insurance fee;
- A signed Student/Parent Laptop Agreement.

The laptop agreement along with copies of *1:1 Laptop Most Frequently Asked Q&A* and *1:1 Laptop Initiative Handbook* can downloaded in both English and Spanish at the school's website. Sophie reported that a technology facilitator was available to her team three hours a week. She indicated that her professional development experiences exposed her to "the presentation of technology only." She described leadership support for technology use at her school as "low." Via email correspondence, we arranged an observation of her 45-minute fourth period class on October 25, 2010.

Sophie's lesson took place in the computer lab because some her students' laptops did not have a working version of MS Publisher. She indicated there had been some problem with imaging the students' laptops and the issue was being addressed, but she had to move on with her language arts project. Some students did have their laptops, but many worked on the Dell desktops in the lab. There was a cart with a laptop and LCD projector, but it was not used during this lesson. The 50′ x 60′ lab had seating arranged in four groups of eight desks. Shelia's 7th grade language arts lesson was the culmination of creating a cookbook where all students were contributing a family recipe. Sophie's students had been studying 2nd person point of view and considering audience when writing.

The analytic component, *using pedagogical techniques that constructively and continuously incorporate technologies to teach content,* of TPACK helped me examine if Sophie leveraged her technology knowledge in conjunction with her pedagogical and content knowledge. It is important to note that no whole group instruction took place during her lesson. Rather, students were in various stages of completing their recipes using MS Publisher, an example is provided in Figure 4.28.

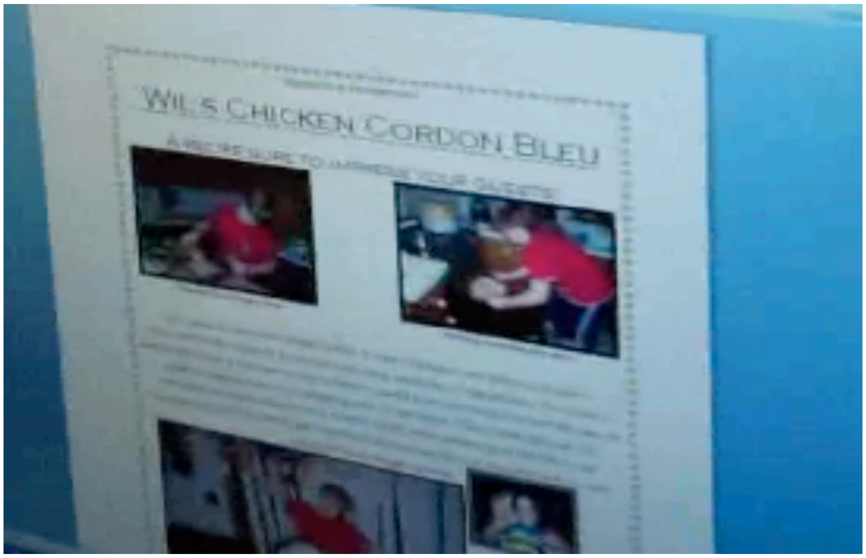

Figure 4.28. Student's recipe in MS Publisher from video.

The majority of Sophia's lesson was in support of helping students format, edit and save their recipes to her folder on the schools server. As such, there was limited evidence of her TPACK in her video, transcript and field note data. Some of Sophie's SRI was about how she had used technology, like VoiceThread, in previous lessons. Some of Sophie's reflection centered on how she felt inadequate to help students navigate through MS Publisher. For example, she shared that "in my head I'm still thinking, 'I can't believe I can't remember how to make the text box.'" and further she declared, "I only use Word at school – at home I use Pages, so I'm trying to remember how to navigate two systems." The majority of her SRI, was dedicated to rehashing why she was supporting students in formatting their recipe layout. Here is one example:

> I just wanted them [students] to work on the layout of their pages. Trying to make them look stronger, we've already told them what should go on Page 1 and what should go on Page 2. Now all of a sudden, she's [student in the current portion of the

> video being viewed] trying to squish stuff on the first page. So tomorrow, hopefully, she'll have all of this on her second page, and I can then help her, if she hasn't already done it, expand that first page.

Many of her comments were related to how frustrated she was about helping students save their work so she can access it. For example, she stated this at one point in her SRI:

> So we have a T drive, that's teachers only, and we also have a student-only P-drive, so technically only they can access the work that's there, but in terms of printing a cookbook, we need to be able to compile all of their pages, so I wanted them to save it on the P-drive. She [student in video] saved it in the wrong place, I'll just have to go back to make sure that everyone's saved his or her recipe in the P drive. If you don't have some sort of system, it becomes chaotic really quickly, because these kids will have 14 versions of the same thing saved all over. So it's definitely important to go over so they can access things later, but it is a tedious thing to teach.

In my field notes, I make several comments about how increasing students' capacity in using MS Publisher and computers in general appeared to be the dominant learner outcome for Sophie's lesson. In fact there are only two events during the lesson, which Sophie commented on, that approached meeting the TPACK analytic component.

As seen in Figure 4.28, the students' recipe has a phrase before the title, Sophia reflected on her interaction with this student:

> I can't remember what it [phrase at the top of screen] said, but it was distracting from the recipe itself. Since I could see it on the screen, it made it easier for me to point it out. I wanted him to think about audience…this sentence, or whatever it was, was not

> that important. So as you see in the clip, we talked about how he should move to somewhere else in his recipe.

Although this was not intentional, Sophie's thinking does capture an inkling of how her pedagogy, discipline knowledge and use of technology could further support her students' skill in considering audience during the act of writing.

As shown in Figure 4.29, one student had not made very much progress on their recipe. I made note of this interaction because the student became very agitated and kept repeating, "I don't know what 2nd person means."

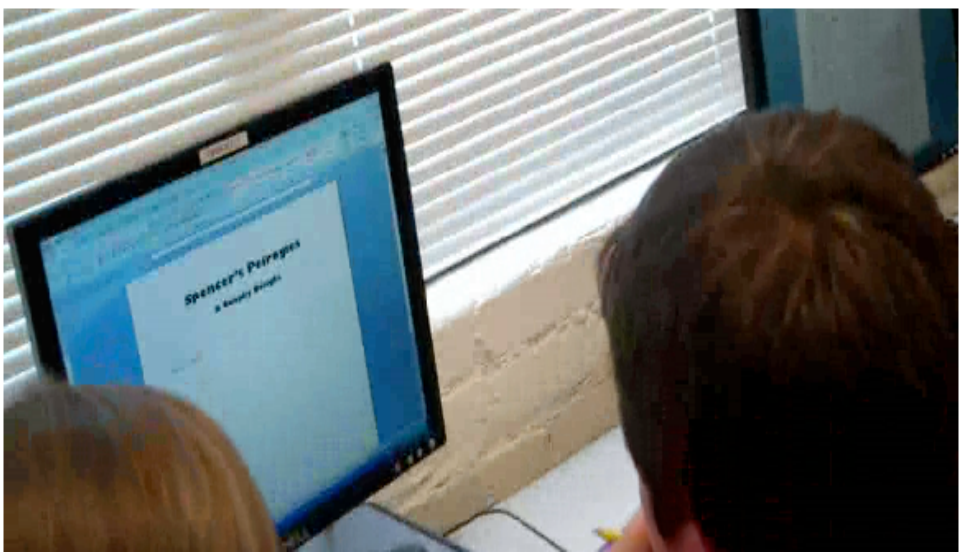

Figure 4.29. Student's incomplete recipe from video.

Sophie reflected about this interaction as follows:

> Spencer really struggles with writing. I was hoping that getting him to write a recipe would sorta sneak in the concept of 2nd person point of view. I thought the computer would help him be more productive. I feel like today, I was not able to help him be as productive as I would have liked, because I was being pulled in so many directions.

Again, Sophie's above comment hints at her attempt at balancing her technology, content and pedagogy knowledge.

TPACK case summary. The data in this case illuminated stark differences when using the TPACK framework to understand the complexity involved in observing a teachers' balanced negotiation among their content, pedagogical and technology knowledge. Quite simply, Liam demonstrated sustained TPACK and Sophie did not. This finding may offer challenges to future TPACK research, and will be discussed later in Chapter Five.

Figure 4.30 provides a graphic representation of the TPACK case findings.

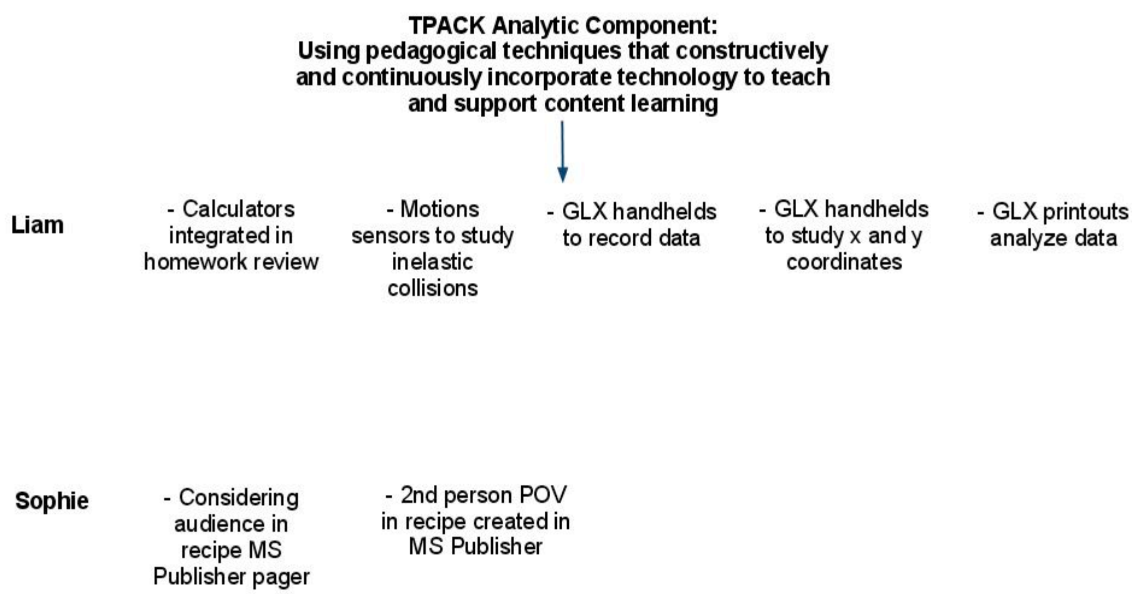

Figure 4.30. TPK case findings by analytic component and markers.

Within-case Findings Summary

Figure 4.31 helps to distill some the major findings from the within-case analysis for the reader.

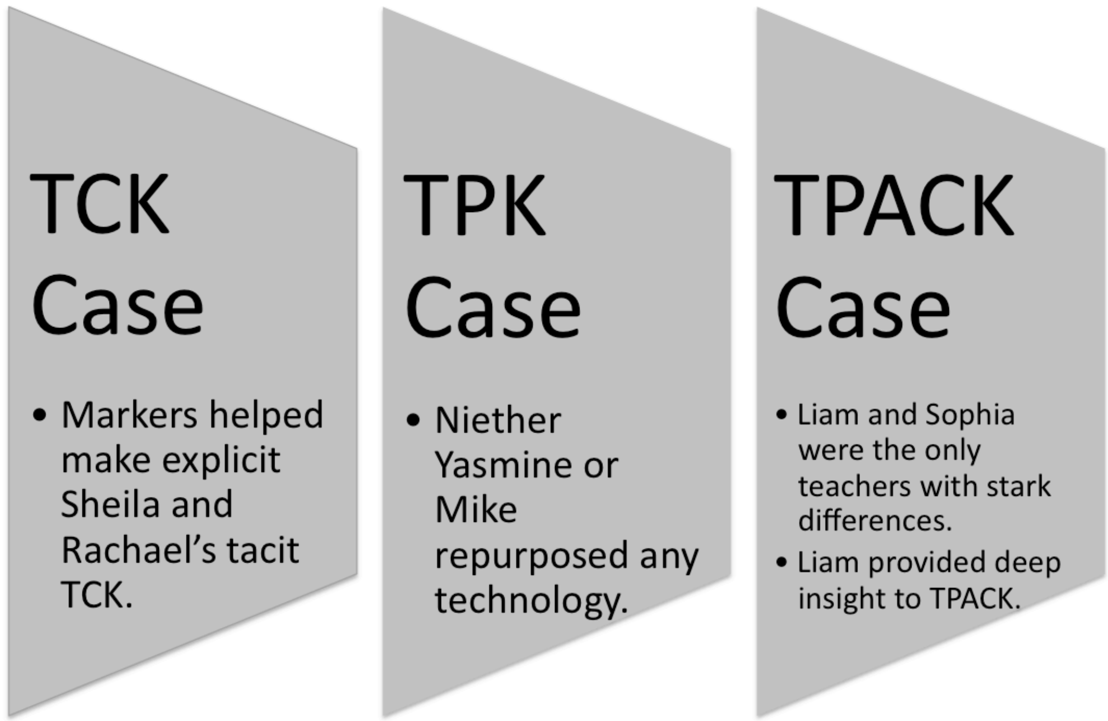

Figure 4.31. Highlights of within-case findings.

The TCK within-case findings brought merit to a matrix recommended by Niess (2008) that helped make Sheila and Rachael's TCK more explicit in their practices. Discovering that neither Yasmine nor Mike repurposed technologies in their lessons was an important TPK finding. The stark differences in Liam and Sophia practice was a noteworthy TPACK finding. Finally, findings from Liam's practices and interviews provided illuminations into the TPACK construct. Further discussions for all of these findings are discussed further in Chapter Five.

Cross-case Findings

As previously discussed in Chapter Three, 14 codes and 3 themes emerged from teachers' semi-structured interviews. The interpretative themes that developed from the teachers' semi-structured interviews were: (a) Helping us Help Ourselves: *"My school will find a way to make that happen for me,"* (b) Help Us Help Students: *"I'm able to identify specific objectives that I need to focus on."* and (c) Help Us Help Each Other: *"We get to practice together."* Illustrative comments were selected for inclusion in the themes to provide additional insights for the reader.

Help us help ourselves: "My school will find a way to make that happen for me." Supportive conditions can positively impact veteran teachers' successful use of technology during instruction. Many teachers in this study alluded to wanting freedom to bolster their own capacity for effectively leveraging technology while teaching in their 1:1 environments. Sheila made it clear in how she has helped herself in this way: "So all of our training is differentiated, you can choose the level that you feel you're at and go to workshops you feel you can handle." Mike shared a similar experience about the professional development offerings at his school: "We're able to choose. I get to ask myself 'Do I want to focus on this particular area or do I want to focus on that particular area?'"

Several teachers emphasized that their schools provide them with the latitude to better manage their own technology choices. Sophie described how her school's culture enabled her to help herself:

> If we deem a website or video to be appropriate, then we can use it. We have to, obviously preview it, but it's just the fact that we can use our professional judgment. If we can find it and like it and feel like it's worthy, then we have this freedom to use it, which is pretty great.

Rachael enjoyed a similar freedom to help herself in her 1:1 setting. She shared: "If a site is blocked. You e-mail your facilitator, and then they'll unblock the site. They trust us here." Additionally, Liam voiced his freedom to help himself at his 1:1 school:

> If I find a new technology I want to get, like a FLIP camera or something, I can bring that to the table. The powers that be will find a way to make that happen for me even if the budget is tight. When teachers say something, it falls on receptive ears. They [administration] have a receptive ear to ideas, especially if I'm coming up with a way to incorporate that technology.

School cultures that help teachers help themselves should not be underestimated. Veteran teachers practicing in 1:1 settings should be encouraged to trust their abilities to appropriately select technologies that they deem necessary to further student learning. It was evident from my data analysis that having this type of freedom was directly related to teachers' personalization of their own learning and bold selections of technology to support and enhance student learning.

On the other end of the continuum, however, several teachers, who were satisfied with general professional development opportunities, expressed frustration in not being helped in more personalized ways. Mike was the most animate:

> I've actually never had someone in the course of my professional development say, 'Hey, look, you're a mid-career teacher, you are sort of facing a dichotomy between your pedagogical knowledge and your technological proficiency - are there things that you would like to do in the classroom that you feel like you're not able to?'

Sophie explained her frustration this way:

> The thing is, I need to see more literacy-based technology applied in an actual classroom. I haven't had any professional development that was designed to help me develop my own lessons using technology in our Web 2.0 environment.

These teachers appear to want more personalized opportunities to learn how to effectively teach with technology.

Help us to help students: "It's a really wonderful thing to see kids get what they need." Several of the teachers in this study shared how their school helped them to help students improve their achievement and meet learning goals. Yasmine shared that in her 1:1 setting:

> We've had training on how to use ClassScape. They taught us how to read the data, so I'm able to identify specific objectives that I need to focus on with my students. It helped to raise their scores and proficiency levels.

Several teachers shared the benefit of their exposure to new understandings about how specific technologies could make learning goals achievable by their students with differing abilities. Sheila shared how her school helped her help her students:

> A few weeks back, they [school] brought somebody in to teach us about VoiceThread. I got to see how I could use it for different learning styles. I hadn't thought about that, but VoiceThread is great for visual learners. You can also add sound. Now I will try to use it more.

Mike shared a unique situation in which his school petitioned to help his students get what they needed:

> I went to my principal and said, 'These kids don't have laptops, and their parents aren't going to send them with money.' She went to our superintendent. He created a program where kids who were on food stamps, which are my whole class, could bring documentation that they receive food stamps, like a monthly statement, and we would waive the laptop fee. And so within about 10 days after that meeting, every single kid in the class had laptops. It's a really wonderful thing to see kids get what they needed.

Purposefully helping these teachers help their students capitalize on the availability of laptops and effectively increase student learning when using technology was invaluable. This kind of school culture enabled these veteran teachers to more effectively leverage technology in their 1:1 setting.

Help us help each other: "We get to practice together." Sustaining and realizing the benefit of ubiquitous computing requires a strong sense of school community. Many teachers in this study were provided opportunities to seek help from each other to better their technology integration. Yasmine shared how her 1:1 school helps its teachers help each other:

> We have staff development 2 days a week on Tuesdays and Thursdays. We gain some type of new technological skill, whether it is how to use enhanced web sites or just utilizing the programs, etc. We get to talk with each other about how we can use these in our classroom…how to use the new cameras or whatever it may be. I think that's the best part.

Some teachers in this study were also encouraged to recognize their colleagues' expertise. Rachael explained that, "about once a month, you have to do a lesson. You plan a lesson, you go into a class and you teach it. Everybody gets to watch you. If you're the expert, you get to share that." Liam shared a similar practice in his school, "so people will come back from a conference and share things that they've learned. They're really empowered to share it, and that definitely helps." Mike described his experience this way, "Sometimes during our PD we get to say 'Tell me what you're doing in your classroom.' or 'Have you thought about this?' 'What are the barriers to trying this?'"

Teachers have long been working closely with each other to further develop their skills to better facilitate effective learning for their students. This ongoing collaboration appeared to take on new life when these teachers were provided ubiquitous technology in their 1:1 classrooms. Part of this new life, however, appeared to include a perceived chasm between teachers of different generations. Unprompted by me, some of the teachers in my study expressed concern that their collaborative efforts with colleagues are hindered by their veteran status. Mike makes this clear:

> The newer teachers, in my own English department maybe they believe, like there is a lapse of technology use in my classroom, so I am seen as a veteran teacher…so I can't *possibly* be a leader or a pioneer in this particular area (emphasis noted in my field notes).

Sophie shared a similar experience that raised the same feelings in her:

> I felt like the younger teachers, even with just a 5 to 10 year difference, make a big deal on how they use technology versus how I use it. I had an interesting conversation at the teacher table at lunch the other day. Someone told me that I was of a 'different technological generation' than they were, and they only were 3 or 4 years younger

> than me. I said, 'That is not true! I Facebook!' It was just a superficial conversation. But it is an interesting thought…how do we stay current and try things that are completely new to us that we may not be using in our daily life, and then bring them into the classroom?

Liam shared:

> I think as a veteran teacher it's such a preparation thing. If you iron out the kinks [of technology] by doing a test or doing it yourself, that of course takes time. It would be nice if the younger teachers would step up more and share their skills.

These teachers are certainly facing challenges that may be brought on by generational differences between them and their peers. This will be further discussed in Chapter Five.

Summary of Cross-Case Findings

What have these veteran teachers' experienced while practicing in 1:1 settings? Many of these teachers felt empowered to freely make instructional choices that they felt best impacted their students' learning and achievement. Evidence of evolving forms of professional development and collaboration opportunities included: (a) some self-selection of learning; (b) showcase of new skills; and (c) identification of technologies that support instructional differentiation. Many teachers felt free to, and were successful in, advocating for technologies that allowed their students to thrive. However, several teachers expressed some frustration with their professional development opportunities as well as their relationships with younger colleagues. Chapter Five further discusses veterans' teachers' diverse learning needs and collaboration challenges in 1:1 settings.

CHAPTER FIVE: DISCUSSION

This study used a sequential mixed method design as a vehicle for answering the following research questions:

1. How do revisions made to the *Survey of Teachers' Knowledge of Teaching and Technology* impact its reliability and validity for use with secondary teachers?
2. What are the self-reported levels of secondary veteran teachers' technological pedagogical content knowledge (TCK, TPK, and TPACK) practicing in 1:1 settings?
3. How are veteran teachers' technological pedagogical content knowledge (TCK, TPK, and TPACK) reflected in their instructional practices implemented in 1:1 settings?

In the first phase of the study, 81veteran secondary teachers completed an adapted version of the *Teachers' Knowledge of Teaching and Technology Survey.* The survey queried these teachers about their demographical information as well as their self-perception of their ability to effectively use technology during instruction. These teachers had eight or more years of service and were practicing in 1:1 settings that ranged from 6th to 12th grade. In Chapter Four, I reviewed the findings from the adapted survey, including teachers' self-reported averages for technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK). In addition, I addressed how issues of reliability and validity for the adapted survey were approached and handled.

In the connecting phase of the study, three cases (two teachers each) were selected to better examine participants' TCK, TPK, and TPACK self-perceptions during practice. Sheila and Rachael made up the TCK case. Yasmine and Mike were in the TPK case. The TPACK case included Liam and Sophie. In Chapter Four, I provided background information about these teachers along with an overview of their school and observed lesson.

In the final, qualitative phase of this study, I used the TPACK framework as the within-case analytic lens. Specifically, the *a priori* within-case analysis and coding was aligned to the three TPACK sub constructs (e.g., TCK, TPK, and TPACK). TCK was assessed via two analytic components: (1) *using technologies best suited for addressing content learning* and (2) *using technologies that best simulate or represent content domain knowledge.* The markers for the first TCK analytic component were: (a) declarative, (b) procedural (c) schematic, and (d) strategic. The markers for the second TCK analytic component were: (a) represented via video, (b) represented in audio only, (c) represented by using images, SmartBoard, or class website, (d) represented directly by the Internet/Web2.0 tool or application. *Using technology as part of a pedagogical strategy* was the analytic component for TPK. The associated markers were: (a) general, (b) repurposing, and (c) considering student learning. The analytic component for TPACK was *using pedagogical techniques that constructively and continuously incorporate technologies to teach content* and no markers. In addition, 14 codes and 3 themes emerged when I used open coding during cross-case analysis of teachers' semi-structured interviews. In Chapter Four, I reviewed the findings from the study in an attempt to better understand veteran secondary teachers' TCK, TPK, and TPACK along with their practices and professional experiences in 1:1 settings.

In this chapter, I advance three concluding themes that emerged from synthesizing findings across both the quantitative and qualitative data: (a) And the Survey Says…, (b) Illuminated TCK, TPK, and TPACK, and (c) The Veteran Teacher, TPACK, and the 1:1 Setting. In the first section, I highlight issues of reliability and validity associated with the adapted version of *Teachers' Knowledge of Teaching and Technology Survey* along with the implications for future research. In addition, I discuss how veteran teachers' TCK, TPK, and TPACK scores (e.g., self-perceptions) from this study extend TPACK and other educational research. In the second section, I demonstrate how the *a priori* within-case analysis approach used in this study better illuminated these veteran teachers' TCK, TPK, and TPACK and thus adds to the TPACK theoretical framework and related literature. Recommendations for future research are offered where appropriate. In the third section, I draw attention to how findings in this study's cross-case analysis provide unique insights into the challenges veteran teachers experience while practicing in 1:1 settings. I conclude with a summary of future research recommendations that may enable researchers, administrators and policy makers to address the challenges that veteran teachers face as they strive to transform their practices for the 21st century.

And the Survey Says…

I conducted an exploratory factor analysis (EFA) on 81 secondary teacher responses to better examine the subscales that I adjusted in the adapted *Teachers' Knowledge of Teaching and Technology Survey* (e.g., TCK and PCK subscales). I hoped the EFA results would begin to answer the first research question: How do revisions made to the *Survey of*

Teachers' Knowledge of Teaching and Technology impact its reliability and validity for use with secondary teachers?

It was important to examine the factors that were produced by adapting the survey and how these factors (e.g., TK, CK, TCK, TPK, and TPACK, etc) aligned to the TPACK framework. Comfrey and Lee (1992) suggested, "the greater number of variables with substantial loadings, the easier it is to isolate what the factor represents" (p.241). DeWinter, Dodou and Wieringa (2009) conducted a series of small *N* data simulations and found that for most research objectives a large sample size is required to produce useful EFA results (i.e., low to medium loadings and relatively large numbers of factors). Specifically, when factors are not well defined (i.e., loadings) or their numbers are large, a small sample size EFA may not yield valid or reliable solutions. The exploratory EFA results provided little to no factor loadings that could be deemed as appropriate to organize into factors that aligned to the TPACK framework; there were limited factors loading at the recommended .30 or .40 (Sass, 2010). In addition, I anticipated having at least seven factors based on the TPACK framework. Thus, I rejected the EFA results as evidence for assessing emerging validity and reliability of the adapted *Teachers' Knowledge of Teaching and Technology Survey*. These findings indicate that the validity and reliability of the adapted survey requires more extensive investigation. A series of studies is clearly needed to develop additional items for many of the original subscales, especially those in which only three items, to help better determine what factors exist in the adapted survey; and, further, to discover what potential the adapted survey offers in TPACK theory building and description?

Even though, I was unable to use my EFA results to establish emerging reliability and validity, I found that the adapted *Teachers' Knowledge of Teaching and Technology Survey*'s subscales possessed sufficient levels of reliability. Moreover, I only adjusted one subscale (TCK) in the adapted survey that was included as a focus in this study. Consequently, I decided to move forward in answering my second research question: What are the self-reported levels of secondary veteran teachers' technological pedagogical content knowledge (TCK, TPK, and TPACK) in 1:1 settings? The average (n=81) self-reported teacher response, along a five-point scale for TCK, TPK, and TPACK, was 3.89, 3.98 and 3.98 respectively. The differences between TCK and TPK, albeit slight, are representational of an ongoing debate about differing pathways teachers take when acquiring TPACK. Cox's (2009) conceptual analysis of TCK, TPK, and TPACK led her to suggest, "secondary or post secondary teachers most likely should begin with TCK and then develop TPACK" (p. 96). On the other hand, it could be proven in future research that secondary teachers should develop their TPK then translate that to their TPACK. Mishra and Koehler (2008) offered that teachers might be better served if they develop TPACK in a "gradual and spiral-like manner" that is driven more by teachers' "subject matter and context" rather than a set sequence (p. 22). Questions about divergent and best pathways to TPACK warrant further research. Specifically, some important questions going forward are: How do differences in veteran teachers' TCK and TPK impact their full development of TPACK? To what extent does the specific content knowledge possessed by a veteran teacher shape their pathway in learning TCK, TPK and TPACK?

An interesting byproduct of this research was that several of the teachers appeared to have perceived their level of TCK, TPK, and TPACK, in the qualitative phase, differently than their observed practices indicated in the qualitative phase of this study. As a reminder, in the connecting phase of the study, I transformed teachers' raw scores (n=81) to z-scores to select teachers with diverse self-reported TCK, TPK, and TPACK for further study. Contrasting veteran teachers' with high and low TCK, TPK, and TPACK might have emphasized how these differences impacted their practice. My analysis revealed that only Liam and Sophie's self-report of high and low TPACK, respectively, aligned to their observed instructional practices. Little distinction in observed instructional practices existed between the high and low teachers in the TCK (e.g., Sheila and Rachael) and TPK (e.g., Yasmine and Mike) cases. It is impossible to ascertain whether, Shelia, for example, overestimated her TCK and therefore her practice was similar to Rachael's or vice versa. This phenomenon, relating to inaccuracies in teachers' survey self-reports, has been well documented in other educational research. For example, Knezek, Christensen, Mayes and Morales (2005) compared technology integration specialists' ratings of teachers' practice against teachers' self-reported ratings of their practice using the Apple of Classroom of Tomorrow (ACOT) Stages of Development (e.g., survival, mastery and impact). They found that the "observers reported the teachers 26.3% lower than the teachers reported themselves" (p. 897). Similarly, Kophch and Sullivan (2007) found that 8th grade teachers' self-reports of their practices related to educational technology yielded data that was "inaccurate because they indicated greater-than-actual teacher use of these practices" (p. 640). The results of these studies are consistent with my findings; teacher self-report data about technology use can be misleading. Therefore, how to best evaluate veterans' teachers TPACK self-reports may require more study.

This study's quantitative findings collectively imply that future research is required to create a reliable and valid TPACK self-report instrument for secondary teachers. Moreover, additional measures related to how self-reports are indicative of practice may be necessary to fully capture veteran teachers' TPACK.

Illuminated TCK, TPK, and TPACK

The third research question was: "How are veteran teachers' technological pedagogical content knowledge (TCK, TPK, and TPACK) reflected in their instructional practices implemented in 1:1 settings?" The within-case analysis in this study significantly illuminated the participating teachers' respective TCK, TPK, and TPACK. Groth, Spickler, Bergner and Bardzell (2009) posited that teachers' classroom instruction when observed through the lens of the TPACK framework can identify important theoretical constructs in their practice. This study's findings support their claim. The use of *a priori* coding, based on the TPACK conceptual framework, helped to highlight important aspects of these veteran secondary teachers' knowledge and practice. Findings from this study added to various under-theorized aspects of the TPACK framework and will be discussed, in detail, in the following sections: (a) Explicit TCK; (b) Repurposing TPK, and (c) Illusive TPACK.

Explicit TCK

TCK is defined as a teacher's knowledge of appropriate technologies for teaching concepts associated with a specific content area. In general, Sheila and Rachael were readily able to discuss the relationship between technology and their content. For example, Sheila recalled her thoughts about technologies she used to teach language arts:

> I used different technologies to present the different parts of mood and tone, and then I brought it all together on the wiki. Sometimes technology can help me to teach part of it [content], sometimes the technology is right for the whole thing. Language arts have multi-directionality and with technology, I can move back and forth. I can stop right there, where a word is, I can just click and, BOOM! I can put VisuWords on the screen, full-screen. I show all of the different relationships, find the meaning of the word, and then go back and re-read that sentence with an understanding that is in context. That's using technology and connecting it to content immediately.

She added humorously, "It's about what the tool can do for you, I mean, there's no use in using a spoon if you're eating French fries." Rachael had similar thoughts:

> Doesn't the SmartBoard scream "language arts" to you? The ease of conveying information is so quick and fast, that's why I like it. I use it for formative assessments so that I can check the [students] knowledge quickly and move on. We used to use the whiteboards for that, and I found that this works so much better.

The very nature of TCK, however, makes it difficult to adequately identify teachers' tacit knowledge during practice. Rather, teachers' knowledge of the relationship between technology and content is situated in their thought processes. The *declarative* (knowing the content knowledge), *procedural* (knowing how to use content knowledge), *schematic* (knowing why to use content knowledge) and *strategic* (knowing when and where to use content knowledge) markers proved helpful in parsing out TCK evidence in both teachers' lessons. These markers brought a greater clarity to how Shelia and Rachael's TCK impacted their practice with technology. Shavelson, Ruiz-Primo, Li and Schultz (2003) posited these markers as a matrix to *bring clarity to thinking about thinking* when assessing students' science content knowledge. Niess (2008) recommended using this marker matrix to strategically guide pre-service teachers' thinking while writing content specific technology enhanced lesson plans. She asserted that this matrix provided teachers with "a process of framing, organizing, and clarifying their thinking about the content and technology they plan to include in their lesson" (p. 233). That is, the marker matrix may help teachers make clear their thinking about content goals and objectives along with their rationales for including technology during instruction. Indeed, the marker matrix better helped highlight both Shelia and Rachael's actions and reasoning that formed their TCK. Even further, I was able to demonstrate that their TCK was evident up and down the matrix's continuum as seen in Figure 5.1.

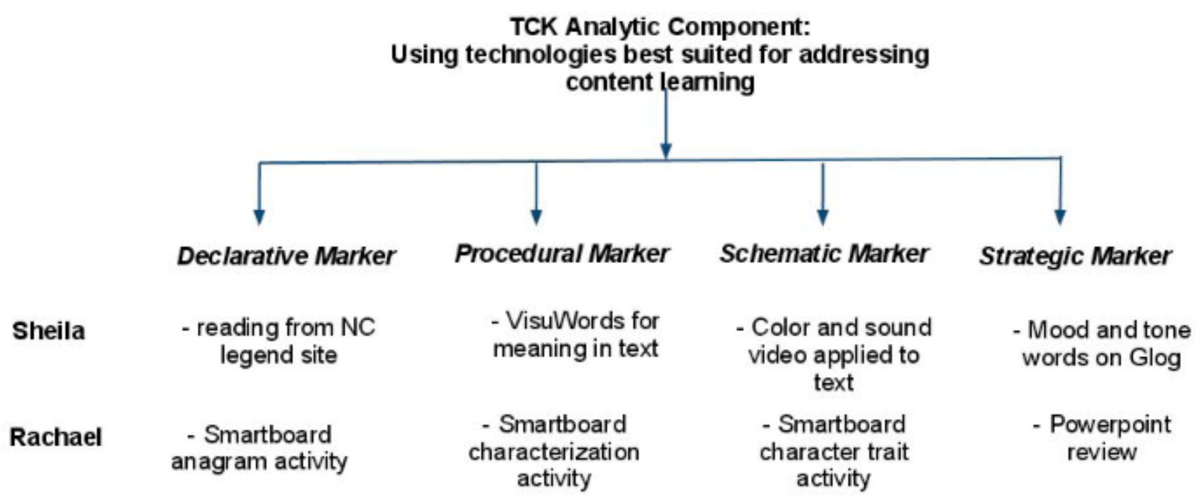

Figure 5.1. TCK case findings by analytic components and markers.

Rachael and Sheila both exhibited knowledge of how to guide their students' content learning through transformational and appropriate technologies. The matrix makes clear that both teachers know how to teach their content with technologies serving as tools for scaffolding students' learning to the highest evolution (e.g., strategic level). Overall, I assert that the marker matrix recommended by Niess was munificent in providing the best means of analyzing these teachers' TCK. Moving forward, this matrix of markers may enable researchers to cross content area boundaries, deepening their insight into all teachers' TCK. Moreover, this marker matrix may prove to be the best lens to make TCK "observable" for all. More evidence is needed to either support or refute these claims.

Repurposing TPK

TPK refers to a teacher's knowledge of how technologies can aid general pedagogical aims and how technologies impact student learning. As seen in Figure 5.2, Yasmine and Mike were adept at using technologies for general pedagogical purposes.

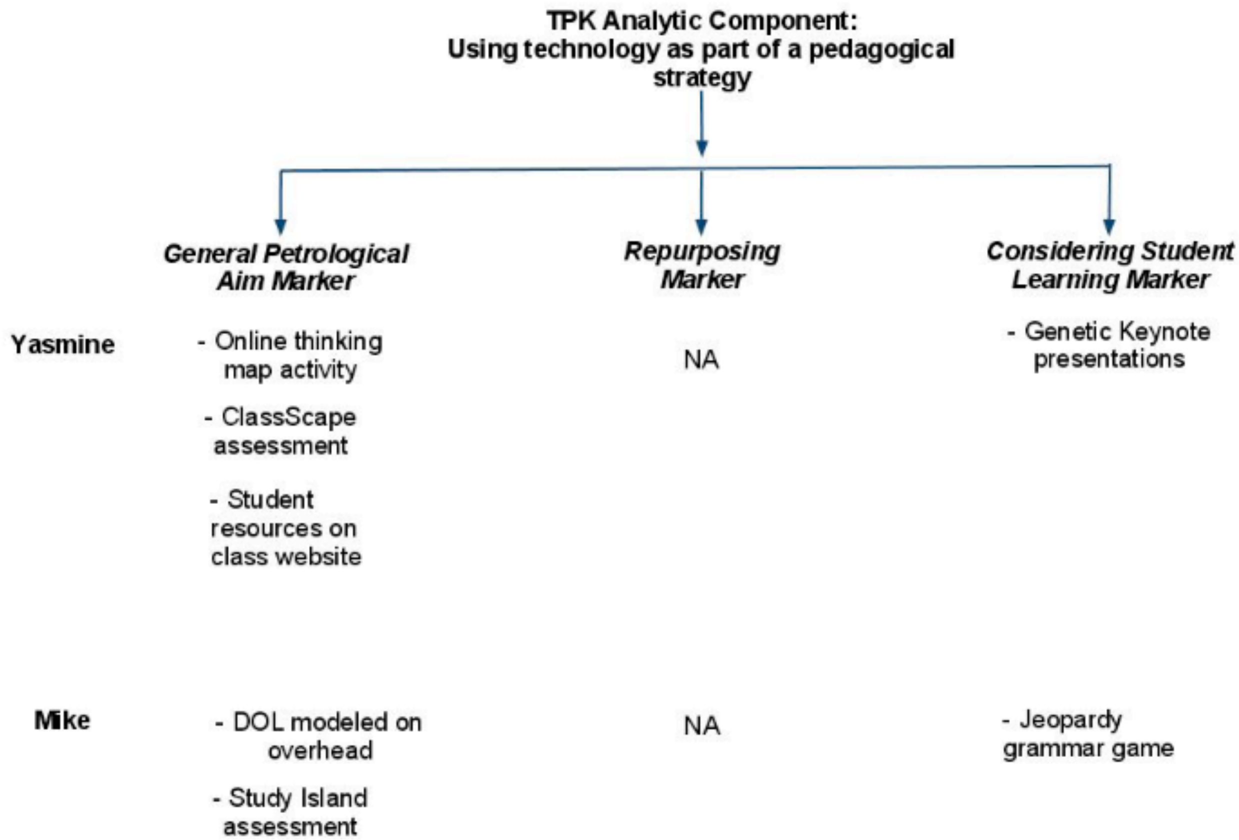

Figure 5.2. TPK case findings by analytic component and markers.

During their interviews, both teachers made clear how they take time to think about how technology influences their students' readiness for learning. For example, Yasmine shared, "Before I plan something, I have to think of a way to make sure that every student is engaged. I want to make sure the technology is the right choice." Mike shared a very similar thought process when reflecting on his Web 2.0 Jeopardy game:

> They're [students] drawing off of each other in terms of engagement. That was what I was hoping to achieve through the use of that particular technology. I wanted an activity that was collaborative and a little bit more fun and engaging. I think that the online Jeopardy does achieve that.

However, Mishra and Koehler (2008; 2009) insist that a key competency associated with TPK required teachers to go beyond their fixed and traditional knowledge of particular technologies to repurpose them in creative ways that are well suited to their students and content area. That is, veteran teachers need to be skilled at repurposing because many of the available technologies were not originally designed for educational purposes. For example, blogs, wikis, and GPS systems were not specifically designed for educational use, therefore teachers must repurpose them for use in their instructional practices. Such repurposing requires deep experiential understanding of the technology and deliberate practice with those technologies in the repurposed manner (Mishra & Koehler, 2009). The TPK markers helped to highlight that neither Yasmine nor Mike demonstrated "repurposing" in their instructional practices or reflections. In each of these teacher's cases, the technology used was not re-constructed for educational purposes. This is significant because teachers' TPK is not completely developed until they acquire "flexible knowledge" of technologies (Koehler & Mishra, 2008, p. 17). Neither teacher in the TCK case redesigned or even subverted the original intentions of the technologies used in their lessons. As such, a worthwhile objective of the TPACK research agenda is to better understand how to help secondary veteran teachers' fully develop their TPK, where repurposing of technologies to support and enhance their students' learning is a central aim.

Illusive TPACK

TPACK describes teachers' perpetual balancing of their technological, pedagogical and content knowledge while teaching. According to Mishra and Koehler (2006), seeing a teacher's TPACK is "an analytical act and one that is difficult to tease out in practice" (p.

1029). As evidenced in Figure 5.3, the combination of collecting both observational and interview data during this study proved useful in better examining and identifying Liam and Sophie's TPACK.

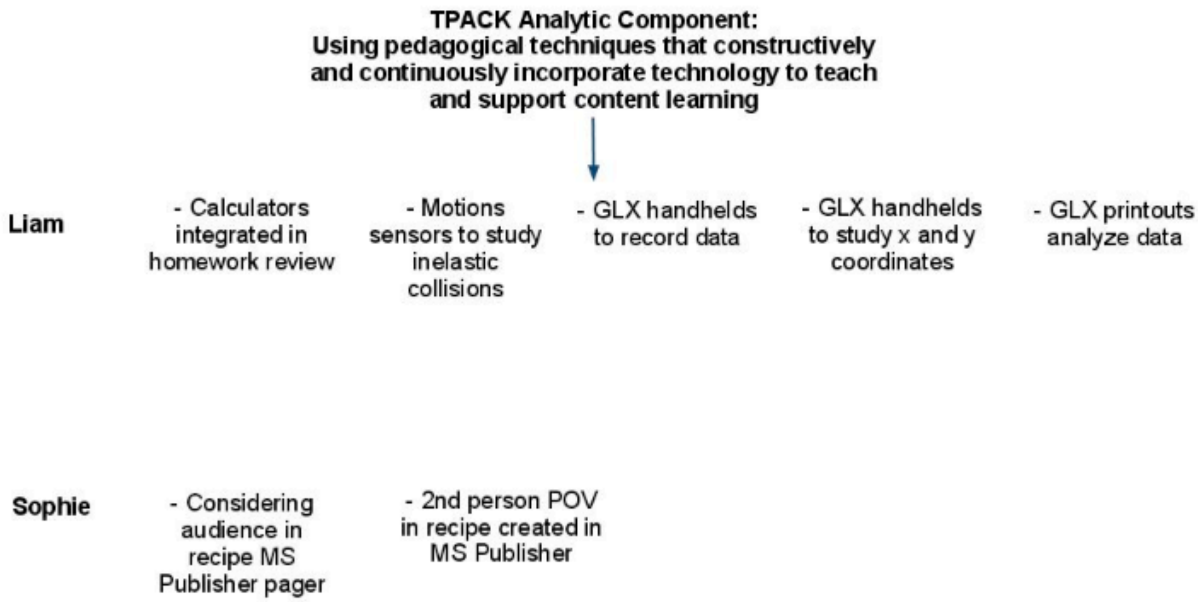

Figure 5.3. TPACK case findings by analytic components and markers.

Mishra and Koehler (2006) also explained that "teaching and learning with technology exists in a dynamic transactional relationship between the three components in the framework; a change in any one of the factors has to be 'compensated' by changes in the other two" (p. 1029). Further, to teach well with technology, teachers must constantly create, maintain and *re-establish* the equilibrium among all three TPACK factors (Koehler & Mishra, 2008). To date, there is little evidence reported in the literature that captures this unique TPACK phenomenon. Liam's stimulated recall interview provided ample evidence of this complex transaction. Specifically, he explained:

I want to do an activity, use a technology and get to the principles. It's like you are on a

> roller coaster ride when you're mixing all of these things together. You get on and when the ride is going on, you are constantly catching your breath. When you go on this roller coaster ride, it's great fun and it's exhilarating, and it's awesome. That's what happens when you have the kids engaged and learning with technology and I am teaching. Does that make sense?

He continues with his rollercoaster analogy to shed light on how he *re-establishes* his TPACK:

> Okay, just like when you get off the roller coaster, you're like, "Wow, that was fun, let's do it again." It [TPACK] exists for a certain bit of time, but then it comes and goes. You know it when you've got it. You have all these things going, you know you've got that match. Oh, it's such a fragile thing because it comes and it goes and you know when it's over.

The *a priori* coding used in this study captured how a veteran secondary teacher uniquely and actively weaved together the factors associated with TPACK. Liam's testimony allowed a privileged peek into how he actualizes and articulates his fluid maneuvers within the space defined by his technology, pedagogy, and content knowledge. In fact, it also brings greater clarity to finding in Spires, Hervey and Watson's (in press) study where they investigated how an inquiry learning project (ILP) model scaffolded TPACK development in twenty in-service English/language arts (ELA) teachers. One of the teachers in their study reported, "I can feel my brain changing" (np) when attempting to articulate her newly constructed connections within her TPACK. Future research should include extended observations paired with interviews directly aimed at exploring teachers' thoughts and feelings that support their actions when using technology during instruction viewed through a TPACK theoretical lens.

The Veteran Teacher, TPACK, and the 1:1 Setting

How the generational related characteristics teachers' possess impact their approach to technology in 1:1 settings has received little attention. It wasn't until 2001, when Prensky posited that two groups of technology users exist: (a) digital natives or (b) digital immigrants, with digital natives being born during the age of technology. In other words, digital natives have spent their entire lives surrounded by computers, videogames, MP3 players, cell phones, and all the other ubiquitous tools of the digital age. Oblinger and Oblinger (2005) offered some additional insight to generational differences associated with technology. They claimed that technology users who fall in the digital native camp have an elevated ability to: (a) read visual images (b) shift attention and provide fast response, and (c) learn better through inductive discovery. Their analysis suggests that digital immigrants may experience a transitional period before there skills match those of digital natives. Dwyer, Ringstaff and Sandholtz (1990) found that "new patterns of teaching and learning" occurred when teachers had unprecedented ubiquitous access to technologies like those in 1:1 settings (p.4). In fact, many veteran teachers have reported having difficulty maximizing the access to 1:1 laptops to facilitate complex and enriching instructional activities (Bebell & Kay, 2010; Dunleavy, Dexter & Heinecke*,* 2007). This makes sense, since Koehler and Mishra (2006) claim that thoughtful use of technology is largely based on a teacher's ability to intertwine their pedagogical, content, and technological knowledge. They suggested that best practice with technology involves "knowledge of the existence, components and capabilities of various technologies...used in various teaching and learning settings and...knowing how teaching might change as the result of using particular technologies" (p.1028). Taken together, this interrelated body of research suggests that teachers across all generations will face challenges in developing their TPACK in 1:1 settings. My study has provided a small portal into the secondary veteran teacher experience in 1:1 schools. The two major generational struggles these veteran teachers perceived are better described in the next sections as: (a) Generational Struggle: Getting the help we want and need, and (b) Generational Struggle: Us versus them.

Generational Struggle: "Getting the help we need and want."

In general, teachers in this study reported that they were satisfied with professional development that has been offered at their schools, especially when it was self – selected. This type of autonomy helped them to improve their confidence and ability to effectively use technology in more relevant ways. This is similar to what Bebell and Kay (2010) found in their two-year assessments of teacher preparedness in a Boston area 1:1 laptop initiative. However, some of the teachers in my study felt they could be better supported when it came to how professional development was managed and delivered. Mike commented:

> Our county has been kind of top-down when it comes to professional development. It feels like, 'These are some objectives that we want to achieve, this is how we're going to achieve them. These are some needs that we perceive you have and so this is what we're going to do to fill those needs.' There has been less of, 'Hey, what do you need? What can we do to help you?' I think there is a disconnect between what we need and what we've been provided.

Like Mike, it was apparent that Rachael felt she was not receiving the type of help and support she really wanted when she shared:

> I just wish they [Administration] would ask what I needed. We're in this meeting, and we're in that meeting. We need time to just sit and play with our damned equipment. We just need time.

Sophie illustrated her experience with professional development at her school in this way:

> In terms of professional support, there are two things I've noticed. One is that our county has a real emphasis on us just getting the hours of professional development. Second, they don't care what it is in, they just want to make sure we have the professional development.

These findings further demonstrate how differentiated and personalized professional development might aid these teachers in better leveraging technology during instruction as well as simultaneously stimulating TPACK growth and development.

Generational Struggle: "Us versus them."

The National Education Technology Plan (NETP) (2009) calls for teachers to "tap into experts and best practices for just-in-time learning and problem solving and design and develop resources and share them with their colleagues" (p. 46). It appears that several teachers in this study were experiencing roadblocks in achieving this important 21st century goal. This is unfortunate because Silvernail and Lane (2010) reported that teachers rated "receiving informal help from colleagues" highest across all forms of professional support in Maine's 1:1 initiative (p. 16). That is, these collegial relationships improved their willingness to attempt similar innovations in their own classrooms. However, Prensky (2001) asserted, "those of us who were not born into the digital world but have, at some later point in our lives, become fascinated by and adopted many or most aspects of the new technology are, and always will be compared to…digital immigrants" (p. 2). This sentiment echoed throughout many of the teachers' reflections about their experiences and interactions with peers in their 1:1 settings. Rachael shared her perspective:

> There are teachers, mostly the younger ones, who feel they are at the top of the pyramid. They look down at those who don't have as much knowledge of the technology, including myself. I don't think they have a heck of a lot more technology knowledge than I do. But I do think for the most part that they think we are too intimidated to have a really good sense of the technology. These teachers act like "hands-off, don't touch me" because some of them are much more comfortable using technology.

Sophie was dumbfounded by the fact that her colleagues who were "only 3 or 4 years younger " than her considered her to be part of "a different technological generation." Mike feels separated from his peers because they see him "as a veteran teacher" that "can't possibly be a [technology] leader." These findings are also reflected in a study conducted by Pegler, Kollewyn and Crichton (2010) that looked at how generational attitudes impacted teachers' practice with technology. The authors suggested that it should not be "assumed teachers from the older generations are incapable or unwilling to infuse or learn technology" (p.457). Unfortunately, to some degree, this phenomena was apparent in my study.

These perceptions of "incapableness" may be brought to light when veteran teachers express being overwhelmed with what they *don't know* about technology; the teachers are operating outside of their comfort zone. In fact, Pegler, Kollewyn and Crichton (2010) found a "marked difference in comfort levels in use of multimedia with the youngest generation reporting the highest level of use" (p. 452). Sheila shared her sense of *imbalance*:

> In the beginning of this initiative, we were all pushed out of our comfort zones. It's been very difficult for those of us who have never used technology to teach. It has been easier for other teachers. For them is was like "Eureka!" For me, I was pushing myself constantly.

In describing her experience as an 18 year veteran, Rachael felt that she had "allowed the technology to intimidate" her because she felt she had to always "do it right in front of others."

Pegler, Kollewyn and Crichton (2010) suggested that schools should "support the establishment of co-mentorship between generations (p. 457). As 1:1 initiatives expand, the field may be better served to continue to research the added value of organized and informal collaboration with younger peers in transforming veteran teacher practice in 1:1.

Conclusion

Technology integration as a "wicked problem" serves as an appropriate metaphor for the novel and dynamic changes facing all teachers. This study offered greater clarity of secondary veteran teachers' TCK, TPK, and TPACK along with their instructional practices in 1:1 settings. Teachers in this study are clearly coming to grips with the new paradigms presented for fully developing their TPACK. Specifically, this study helped make tacit concepts within the TPACK framework more explicit. In addition, this study facilitated a better understanding of what veteran teachers find supportive as well as the struggles they face in their 1:1 schools. Harris (2008) purports that true technology integration is "the pervasive and productive use of educational technologies for purposes of curriculum-based learning and teaching" (p. 252). My study suggests that future research involving TPACK theory building and description as outlined above will have major implications for how to best support secondary veteran teachers' successful development of technology infused lessons that increase their students' learning and achievement.

As the theory, research and practice of TPACK evolves, at least three areas should be taken into consideration. First, it is essential to create a valid and reliable instrument aimed at measuring secondary teachers' TPACK. Without this assessment tool being readily available to the education community, it will be difficult to capture the changing nature of TPACK within secondary teachers' knowledge and practices. Second, veteran teachers will need customized, just-in-time professional development to help them acquire nuanced and critical understandings of how to best use their 1:1 technologies to enhance student content learning. Third, as 1:1 schools develop their professional learning communities; they should be intentional in leveraging veteran and novice teachers' skills and talents in tandem. Veteran teachers tend to have richer content and pedagogical knowledge as the result of years of experience in the classroom; likewise novice teachers have the advantage of growing up in a digital age and tend to take more risks in applying technologies in their classrooms. Creating space for formal and informal collaborative relationships will help both veteran and novice teachers take advantage of this distributed expertise.

Clearly, veteran teachers want to play an essential role in the intellectual and instructional culture of their 1:1 setting. In order for this to happen, appropriate TPACK assessments should be made available, customized professional development should be in place and generational relationships should be nurtured. 1:1 computing will loom large in the future educational landscape. As President Obama put it "If we want to win the future…then we also have to win the race to educate our kids." An essential element in winning the race is having teachers, including veteran teachers, who use technology innovatively and effectively in the 1:1 classroom.

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APPENDICES

APPENDIX A

INFORMED CONSENT FORM FOR RESEARCH – Phase I – Online Survey Only

Title of Study: Between the Notion and the Act: Veteran Teachers' TPACK and Practice and 1:1 Settings

Principal Investigator: Lisa Hervey **Faculty Sponsor:** Dr. Hiller Spires

INFORMATION

You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of this study is to discover what variations exist in teacher's professional knowledge, including technological, pedagogical and content domains, while teaching in 1:1 computing settings. Your responses will not be shared with principals or other school administrators unless they are reported in aggregate form.

You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. An opportunity to print the survey for your records will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above.

If you agree to participate, you are asked to complete the following online survey about your teaching knowledge for using technology in the classroom using Survey Monkey. The survey will probe you about your classroom technology integration and the development of your Technological Pedagogical Content Knowledge (TPACK). Total participation time for the survey could range from 10 to 15 minutes. You may be contacted for follow up research activities.

RISKS

There should be no risk to you from this research. Questions will be asked about your teaching style and competency. These questions may cause you some embarrassment or discomfort if your confidentiality were inadvertently breached. However, as noted in the Confidentiality section of this document, data handling procedures will be strictly adhered to in order to guard against any type of breach.

BENEFITS

You may benefit from participation, hopefully, from engaging in activities that reveal your knowledge of your classroom technology integration and the development of your Technological Pedagogical Content Knowledge.

CONFIDENTIALITY
The information recorded in this study will be kept confidential to the full extent allowed by law. The following statement, from Survey Monkey, speaks to how your information will remain private when taking the survey "We employ multiple layers of security to make sure that your account and your data remains private and secure. We employ a third-party firm to conduct daily audits of our security, and your data resides behind the latest in firewall and intrusion prevention technology." *No IP addresses or emails are required to access the survey. No reference will be made in oral or written reports that could link you to the project or to your responses. Raw data and identifiable information from the survey will be stored separately on a password-protected computer and backed up separately on a hard drive in a secure filing cabinet in the researcher's home.*

COMPENSATION
You will not receive anything for participating.

CONTACT
If you have questions at any time about the study or the procedures, you may contact the researcher, Lisa Hervey at lisa_hervey@ncsu.edu or 919-513-8518. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919/515-4514).

CONSENT TO PARTICIPATE
"I have read and understand the above information. By clicking below, I acknowledge and agree to the terms, risks and benefits associated with participating in this study." Please print or save a copy of this page for your records.

Subject's signature______________________________ Date _________________
Investigator's signature___________________________ Date _________________

APPENDIX B

INFORMED CONSENT FORM FOR RESEARCH – Phase II- Classroom Observations and Interviews

Title of Study: Between the Notion and the Act: Veteran Teachers' TPACK and Practice in 1:1 Settings

Principal Investigator: ***Lisa Hervey*** *Faculty Sponsor:* ***Dr. Hiller Spires***

INFORMATION

You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of this study is to discover what variations exist in teacher's professional knowledge, including technological, pedagogical and content domains, while teaching in 1:1 computing settings. You recently completed an online survey for the first phase of this study. The researcher is now seeking participates for the second phase of this research project.

You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above.

If you agree to participate, you will be asked to allow the researcher to audio and/or video tape (as per your school policy) a classroom lesson and then partake in subsequent digitally recorded stimulated recall and semi-structure interviews and, and will last approximately 3 hours. The observation and interviews will take place at a mutually agreed time and date. The interviews will be transcribed verbatim and a copy will be sent to you via email to check for accuracy and to make any recommendations for changes that would be more reflective of your experience. The total time required of you may be between three and four hours. Please be aware that if your school policy allows your principal or another school administrator to view the classroom videotape, we may share the recording of your classroom as necessary. Video and audio files will be destroyed at the end of the research.

RISKS

There should be no risk to you from this research. Questions will be asked about your teaching style and competency. These questions may cause you some embarrassment or discomfort if your confidentiality were inadvertently breached. However, as noted in the Confidentiality section of this document, data handling procedures will be strictly adhered to in order to guard against any type of breach.

BENEFITS
You may benefit from participation, hopefully, from engaging in activities that reveal your knowledge of your classroom technology integration and the development of your Technological Pedagogical Content Knowledge.

CONFIDENTIALITY
The information recorded in this study will be kept confidential to the full extent allowed by law. The data files (audio or video and transcriptions) will be downloaded to and stored on the researcher's password-protected computer and backed up on a portable hard drive stored securely at the researcher's home. No reference will be made in oral or written reports, which could link you to the study. Pseudonyms will be used in every instance.

COMPENSATION
You will receive a $25 dollar gift card to Barnes and Noble for participating. If you provide informed consent, but withdraw prior to completion of the study, will still receive the $25 gift card.

CONTACT
If you have questions at any time about the study or the procedures, you may contact the researcher, Lisa Hervey at lisa_hervey@ncsu.edu or 919-513-8518. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919/515-4514).

CONSENT
"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding I may withdraw at any time."

Subject's signature______________________________ Date _________________
Investigator's signature___________________________ Date _________________

APPENDIX C
REVISED SURVEY

Demographic Data:

1. Please list your current school email address (only for verification purposes, it will NOT be shared with anyone). (participant will enter)
2. What is your gender? (male or female)
3. What is your race (Caucasian/White, African-American/Black, Hispanic/Latino, Native American, Asian, Pacific Islander, Arab or Other (participant will enter answer if select other)?
4. How many years of teaching experience do you have? (participant will enter #)
5. What is your primary educational role? (Middle School Teacher, High School Teacher, Special Education Teacher, School Technology Coordinator, Librarian or Media Specialist, Literacy Coach)
6. Which overall content area best represents the majority of classes you teach? (Literacy, Math, Science, Social Studies)
7. Are you a National Professional Board Certified teacher? (yes or no)
8. What is your highest level of education? (undergraduate, masters, doctorate)
9. If you have a masters degree or higher, please describe the type of degree you hold (i.e., Instructional Technology, Leadership/Policy, Content Area Specific)? (participant will enter answer)
10. Do you have a Technology Facilitator available at your school? (yes or no)
11. How would you describe your school setting? (rural or urban)
12. Approximately how many professional development sessions targeting technology use in the classroom have you attended? (participant will enter #)
13. What best describes the majority of the professional development sessions targeting technology use in the classroom have you attended (presentation of a technology/tool only or presentation of a technology/tool in connection to a specific content area)
14. What best describes the type of leadership support for technology use at your school? (strong, moderate, low)

Participants will answer each of the questions below using the following five-level Likert scale:
1. Strongly disagree; 2. Disagree; 3. Neither agree nor disagree; 4. Agree; 5. Strongly agree

Technology Knowledge (TK)
I know how to solve my own technical problems. I can learn technology easily.
I can learn technology easily.
I keep up with important new technologies.
I frequently play around with the 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.

Content Knowledge (CK) (Math Teachers Only)
I have sufficient knowledge about mathematics.
I can use a mathematical way of thinking.
I have various ways and strategies of developing my understanding of mathematics.

Content Knowledge (CK) (Social Studies Teachers Only)
I have various ways and strategies of developing my understanding of social studies.
I have sufficient knowledge about social studies.
I can use a historical way of thinking.

Content Knowledge (CK) (Science Teachers Only)
I have various ways and strategies of developing my understanding of science.
I can use a scientific way of thinking.
I have sufficient knowledge about science.

Content Knowledge (CK) (English Teachers Only)
I have various ways and strategies of developing my understanding of literacy.
I can use a literary way of thinking.
I have sufficient knowledge about literacy.

Pedagogical Knowledge (PK)
I know how to assess student performance in a classroom.
I can adapt my teaching based upon what students currently understand or do not understand.
I can adapt my teaching style to different learners.
I can assess student learning in multiple ways.
I can use a wide range of teaching approaches in a classroom setting.
I am familiar with common student understandings and misconceptions.
I know how to organize and maintain classroom management.

Pedagogical Content Knowledge (PCK) (Math Teachers Only)
I can select effective teaching approaches to guide student thinking and learning in mathematics.
I can select effective teaching approaches to illustrate difficult concepts within my content area.
I can select effective teaching approaches that reflect my student's prior knowledge.

Pedagogical Content Knowledge (PCK) (English Teachers Only)
I can select effective teaching approaches to guide student thinking and learning in literacy.
I can select effective teaching approaches to illustrate difficult concepts within my content area.
I can select effective teaching approaches that reflect my student's prior knowledge.

Pedagogical Content Knowledge (PCK) (Science Teachers Only)
I can select effective teaching approaches to guide student thinking and learning in science.

I can select effective teaching approaches to illustrate difficult concepts within my content area.
I can select effective teaching approaches that reflect my student's prior knowledge.

Pedagogical Content Knowledge (PCK) (Social Studies Teachers Only)
I can select effective teaching approaches to guide student thinking and learning in social studies.
I can select effective teaching approaches to illustrate difficult concepts within my content area.
I can select effective teaching approaches that reflect my student's prior knowledge.

Technological Content Knowledge (TCK) (English Teachers Only)
I know about technologies that I can use for understanding and doing literacy.
I know about technologies that can deepen my content area knowledge
I know about technologies that I can use to represent concepts within my content area.

Technological Content Knowledge (TCK) (Social Studies Teachers Only)
I know about technologies that I can use for understanding and doing social studies.
I know about technologies that can deepen my content area knowledge
I know about technologies that I can use to represent concepts within my content area.

Technological Content Knowledge (TCK) (Science Teachers Only)
I know about technologies that I can use for understanding and doing science.
I know about technologies that can deepen my content area knowledge
I know about technologies that I can use to represent concepts within my content area.

Technological Content Knowledge (TCK) (Math Teachers Only)
I know about technologies that I can use for understanding and doing mathematics.
I know about technologies that can deepen my content area knowledge
I know about technologies that I can use to represent concepts within my content area.

Technological Pedagogical Knowledge (TPK)
I can choose technologies that enhance the teaching approaches for a lesson.
I can choose technologies that enhance students' learning for a lesson.
My teacher education program has caused me to think more deeply about how technology could influence the teaching approaches I use in my classroom.
I am thinking critically about how to use technology in my classroom.
I can adapt the use of the technologies that I am learning about to different teaching activities.

Technological Pedagogical Content Knowledge (TPACK)
I can teach lessons that appropriately combine literacy, technologies, and teaching approaches.
I can use strategies that combine content, technologies, and teaching approaches that I

learned about in my coursework in my classroom.
I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn.
I can provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches at my school and/ or district.

APPENDIX D

Semi-structured Interview Protocol

How would you describe your TCK/TPK/TPACK? (depending on case)

Tell us about any specific experiences that you have had with using or developing your TCK/TPK/TPACK.

How would you describe the level of technology support available in your school? How does this effect your development of TCK/TPCK/TPACK?

How would you describe the culture of your school for technology integration? How does this effect your development of TCK/TPCK/TPACK?

APPENDIX E

Average TCK, TPK, and TPACK from survey results

Years Of Service	TPK	TCK	TPACK
11	4.25	4.00	3.50
28	4.75	4.00	3.75
12	4.25	4.00	4.00
13	4.00	4.00	3.75
15	5.00	5.00	5.00
10	4.50	4.00	4.00
14	4.00	5.00	4.50
10	4.25	4.33	4.75
12	4.00	5.00	4.00
15	4.75	4.67	4.75
20	3.00	3.00	3.25
9	4.25	4.00	4.75
26	4.50	5.00	5.00
26	3.25	3.00	3.25
10	4.00	4.00	4.00
13	4.00	4.00	4.50
13	5.00	5.00	4.75
16	3.50	2.00	2.75
25	4.00	4.00	4.00
8	3.75	3.00	4.00
14	4.00	4.00	4.00
14	3.75	4.00	3.25
14	3.00	2.33	2.75
31	3.50	4.33	5.00
18	5.00	5.00	4.75
34	3.75	4.00	3.75
18	3.50	3.00	4.00
9	4.00	4.00	4.25
22	4.00	4.00	3.50
34	3.00	3.00	2.75
17	4.00	3.67	3.75
15	4.00	3.67	4.25
10	4.00	3.67	4.00
26	3.00	3.00	2.75
18	3.75	3.00	4.00
11	3.25	3.00	3.75
10	4.00	4.00	4.00

APPENDIX E (continued)

Years Of Service	TPK	TCK	TPACK
17	3.50	4.33	4.00
16	4.00	4.00	4.00
18	4.00	4.00	4.75
9	3.25	2.67	3.00
28	3.50	4.00	4.00
35	3.50	4.00	3.75
26	3.75	3.67	3.50
23	3.00	3.67	3.50
10	3.75	3.33	3.00
33	4.00	4.00	4.00
12	3.00	3.33	3.50
14	5.00	4.00	4.50
11	5.00	5.00	5.00
20	4.00	5.00	4.50
16	4.50	4.00	4.00
11	4.75	5.00	5.00
21	3.25	3.00	3.00
8	3.50	3.67	3.75
13	4.00	4.00	4.00
19	5.00	4.33	4.75
13	3.00	3.00	3.50
11	4.00	2.00	3.75
10	5.00	5.00	5.00
9	4.75	4.00	4.50
28	4.00	4.00	4.00
18	4.00	4.00	3.50
30	4.50	4.00	4.75
8	4.00	4.00	4.00
10	4.50	4.00	4.50
8	4.50	4.67	4.50
9	3.00	2.00	2.75
9	4.25	5.00	4.00
17	4.50	3.67	3.75
26	4.00	4.67	4.00
26	3.75	4.00	3.75
10	4.00	4.33	4.00
25	4.50	4.00	4.25
17	3.75	4.00	3.75
10	4.00	4.00	4.00

14	3.00	3.33	3.75
20	4.00	4.00	3.50
9	4.25	3.67	4.00
16	4.00	4.00	4.50
16	4.50	4.33	4.25