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Development and Transfer of Technological Pedagogical Content Knowledge (TPACK) of Special Education Teachers

Aleksandra A. Kaplon-Schilis
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DEVELOPMENT AND TRANSFER OF TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK) OF SPECIAL EDUCATION TEACHERS

by

ALEKSANDRA KAPLON-SCHILIS

A dissertation submitted to the Graduate Faculty in Urban Education in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2018
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Aleksandra Kaplon-Schilis

This manuscript has been read and accepted for the Graduate Faculty in Urban Education in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Dr. Anthony Picciano

THE CITY UNIVERSITY OF NEW YORK
DEDICATION

This dissertation is dedicated to my beloved family. Thank you!

To my parents, Elzbieta and Andrzej Kaplon, thank you for your love, your encouragement, and your endless support. To my husband, Samuel Schilis, thank you for your love, your friendship, your helpful advices, patience, support and for putting up with me on this journey. To my children, Arya and Bedford Schilis, thank you for your endless love, inspiration and for keeping me grounded. To my sister, Kasia Wrzesniewska, thank you for your love, for patiently listening to my complaints, for your support and friendship.
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To my advisor and committee chair, Dr. Irina Lyublinskaya, I am extremely grateful and thankful for her advice, guidance and encouragement throughout the course of this journey. Since the beginning of this journey, she has served as an inspiration, a mentor, and a friend. Her ongoing feedback, patience, supportive kindness, her commitment together with her demands of high expectations and adherence to deadlines - challenged me all in the right ways. Thank you!

I would also like to acknowledge the help, guidance, and time offered to me by my dissertation committee: Dr. Nelly Tournaki, and Dr. Toni Picciano. Thank you!
ABSTRACT

Development and Transfer of Technological Pedagogical Content Knowledge (TPACK) of Special Education Teachers

by

Aleksandra Kaplon-Schilis

Advisor: Dr. Irina Lyublinskaya

This dissertation presents findings of three studies investigating the development and transfer of TPACK of pre-service and in-service elementary school special education teachers. The dissertation is presented in a non-traditional format including an introduction, three manuscripts submitted for journal publication, and a summary chapter. The purpose of the first study was to analyze development of TPACK of pre-service elementary special education teachers enrolled in a graduate level pedagogy course *Integrating Technology in Mathematics and Science Instruction in Special Education and Inclusive Classrooms* in a New York City public college. The study’s research question was to find out whether the TPACK-based course affects TPACK and basic TPACK domains of pre-service special education teachers’ knowledge: TK – technological knowledge, PK – pedagogical knowledge, and CK – content knowledge. The paired sample t-test indicated significant gains in teachers’ TPACK, however there were no significant changes in PK, TK and CK. The first study raised questions of whether the TPACK basic domains are independent of the TPACK domain. The purpose of the second study was to investigate the question raised in the first study i.e., whether TK, PK, and CK are independent
constructs in the TPACK framework and to develop instruments for assessing the basic domains of the TPACK. Exploratory and confirmatory factor analyses suggested that the TPACK construct is independent from TK, PK, and CK. Multiple linear regression showed that TK, PK and CK are not predictors of the TPACK for this population. The purpose of the third study was to analyze TPACK development and a learning trajectory of a single pre-service elementary special education teacher and TPACK transfer from this course to the teaching during the induction to teaching year. It was noted that the graduate pedagogy course played a critical role in developing pre-service teacher’s TPACK. The study suggested several internal (teacher’s attitude towards using technology and preparedness – teacher’s comfort with using technology) and external (access to technology and school support) factors affecting transfer of teacher’s TPACK from her pre-service to in-service teaching experience.
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CHAPTER 1. GENERAL INTRODUCTION

Throughout history new technologies were seen as the “next, best thing” (Mishra, Koehler, & Kereluik, 2009, p.49) that promised to change and improve existing education. The idea behind using new, innovative tools has been to make learning better for all students; however, researchers are debating whether current educational agencies are ready for the challenge of improving teacher education and preparing pre-service teachers for successful integration of educational technologies into their teaching and learning practices (Voogt et al., 2017). Researchers argue that educators are not provided with proper training or preparation on how to use new technologies effectively in their classroom. According to Ottenbreit-Leftwich et al. (2012) many pre-service graduates feel unprepared to use technology effectively in their classroom practice on their first day of in-service teaching. The recent survey conducted by the Edtech and coding company SAM Labs revealed that 78 percent of U.S. in-service teachers feel they have not received the training they need to teach with technology in the classroom (Ascione, 2017). Moreover, in-service teachers do not find specific technology skills they have learned in their pre-service teacher education programs meaningful or relevant to their teaching practices (Beriswill et al., 2016; Lehiste, 2015). Even though teachers are more aware of the importance of educational technology use, relatively few teachers are willing to integrate technology into their teaching activities. Survey conducted by CDW Government LLC (2010) revealed that only 8 percent of the more than 1000 high school teachers surveyed fully integrate technology into their classroom.
In order to address this problem, US Department of Education identified key challenges and solutions to the effective integration of technology in teacher preparation and provided guiding principles on effective integration of technology in teacher preparation programs (US DOE, 2016). These four principles include:

- Focus on the active use of technology to enable learning and teaching through creation, production, and problem-solving.
- Build sustainable, program-wide systems of professional learning for higher education instructors to strengthen and continually refresh their capacity to use technological tools to enable transformative learning and teaching.
- Ensure pre-service teachers’ experiences with educational technology are program-deep and program-wide, rather than one-off courses separate from their methods courses.
- Align efforts with research-based standards, frameworks, and credentials recognized across the field. (US DOE, 2016, p. 9)

Teacher educators have increasingly looked at the theoretical framework of Technological Pedagogical Content Knowledge (TPACK), which is used to describe what teachers need to know to effectively integrate technology into their teaching practice (Mishra & Koehler, 2006). In the last decade, the TPACK framework has quickly become a widely referenced conceptual framework within teacher education, particularly as teacher education programs are redesigning their curriculum to provide a systematic and meaningful way of preparing teachers for technology integration to address the needs of all students (Chai, Koh & Tsai, 2010; Niess, 2011; Lyublinskaya, 2015).
Problem Statement

Government and teachers’ organizations increasingly emphasize the role of technology in teaching. Even though technology has been used for administrative uses in K-12 education since the 1970s (Picciano & Spring, 2013), it wasn’t until 1990s when it started to appear in the classroom in the form of “simulations, games, and integrated learning systems” (p.6) for instructional uses. From 1994, upon establishment of to the World Wide Web Consortium, the use of technology in education changed drastically allowing for access in all industries and professions. Through the 1983 federal government report, A Nation at Risk (National Commission on Excellence in Education, 1983), an emphasis was put on student and teacher productivity. With this belief, technology became the tool “for supporting production processes requiring speed and accuracy” (Picciano & Spring, 2013 p.53). The importance of integrating technology in learning was re-emphasized in the No Child Left Behind Act (2001). A central feature on the NCLB Act is the requirement of a “highly qualified teacher” in every core academic classroom (Boyd et al., 2008). The National Council of Teachers of Mathematics (2008) introduced a Technology Principle as one of six principles of high-quality math education: “Teachers should use technology to enhance their students’ learning opportunities by selecting or creating math tasks that take advantage of what technology can do efficiently and well – graphing, visualizing and computing” (p.25). The National Council for Accreditation of Teacher Education (NCATE, 2008) set standards such that teacher education programs have to prepare candidates “who can integrate technology into instruction effectively” (p.23). Effective teachers maximize the potential of technology to develop students’ understanding, stimulate their interest, and increase their proficiency. When technology is used strategically, it can provide access to learning for all students. Most recently the Council for Accreditation of Educator
Preparation (CAEP) the organization that replaced the NCATE, emphasized the importance of technology integration across teacher preparation curricula: “technology is a critical area that will require new learning and substantial innovation by preparation providers” (CAEP, 2014, p. 28). The organization recommended that technology integration should be “imbedded in every aspect of educator preparation” (p.28), and chose to recognize it throughout the recommended standards as opposed to providing an isolated section for technology standards (Martin, 2015).

Even though nationally educators agree that pre-service teachers must develop 21st century technology skills (Pellegrino, Goldman, Bertenthal & Lawless, 2007), training pre-service teachers and improving the quality of the new teacher workforce is definitely something America has been struggling with (Green, 2010). In response to this struggle, the International Society for Technology in Education (ISTE) created the National Educational Technology Standards for Teachers (NETS.T) to provide instructional support in technology integration (Martin, 2015). The NETS.T framework can be used by teacher preparation programs to develop curriculum that focuses on preparing pre-service teachers for successful implementation of the technology in their future classrooms. According to Parette et al. (2010) despite the ISTE standards, there are still many teacher preparation programs across the United States that don’t see the urgency on preparing pre-service teachers on how to use instructional technology effectively. These programs still operate “under an older, skill-oriented framework that provides technology instruction in a stand-alone course” (Martin, 2015, p.19).
What influences teachers’ use of technology in their classrooms?

Researchers indicate that using instructional technology in a classroom has a positive impact on teaching and learning (Almekhlafi & Almeqdadi, 2010). Well-used instructional technology can allow teachers to tend to individual learning needs of various students (Starr, 2011). However, for many teachers integrating technology in their classrooms presents a challenge (Balmeo et al., 2014). There are many factors that influence teachers’ successful technology integration, e.g. access to technology, resources, training, teacher’s attitude and beliefs, institutional and administrative support, experience, educational policies (Gulbahar, 2008); however, in this dissertation the author focuses mainly on teacher’s preparation to use technology, teacher’s attitude and beliefs towards implementing technology in their classrooms.

The Ability of Teacher Preparation Programs to Graduate Technology-Literate Teachers

Although the availability of hardware, software and Internet connections continues to increase in schools and colleges, many beginning and pre-service teachers do not have the necessary knowledge or experience to incorporate this technology in their classrooms (U.S. Department of Education, 2010). Despite the new ISTE standards, and the other established policies of the various organizations, most teacher preparation programs do not adequately prepare new teachers to use technology in their future classrooms (Dogan, 2012). According to the Walden Study (2008) most teachers reported unsatisfactory levels of support in preparation for the use of technology in the classroom. More than half of the teachers (who completed initial certification) reported that their teacher preparation program failed to prepare them on how to use technology in their future classrooms. There is a big discrepancy between how various teacher preparation programs prepare pre-service teachers on using instructional technology.
Some colleges offer extensive training with technology, moreover they require future teachers to pass technology competency tests before graduating their program (i.e. Hunter, CUNY). Others do not put such an emphasis on introducing and modeling the use of technology to the future teachers, and the only hope of learning how to implement new programs in teaching lies in professional development after teachers start working.

According to findings from a 2006 national survey of 1450 four-year institutions with teacher education programs, 85% of them included a single educational technology course (ranging from basic computer skills to designing technology rich lesson plans (Kleiner, Thomas, & Lewis, 2007). Even though there are some benefits for pre-service teachers associated with taking this type of course, i.e. improvement in self-efficacy or development of technological skills (Divaharan, 2011), Niess (2011) argues that learning about different technologies does not prepare pre-service teachers to implement these technologies in their teaching.

In the current studies, researchers focus on providing and analyzing various strategies that may help pre-service teachers in implementing technologies in their future classrooms (Tondeur et al., 2011). Technology, pedagogy and content are often seen as independent from each other in many teacher preparation courses. In order to provide pre-service teachers with the experiences needed to apply technology to their specific content areas, researchers suggest that technology should be integrated throughout the curriculum (Harris, Mishra & Koehler, 2009; Tondeur et al., 2012; Ottenbreit-Leftwich et al., 2012). Khan (2014) suggest to model technology to specific tasks, to increase future teachers' ability to select and use appropriate technologies in the chosen context and to improve pre-service teachers’ knowledge and skills with respect to the use of technology for teaching and learning.
According to research pre-service teachers are not interested in courses that offer only theoretical usage of technology, but rather in the courses that combine the theory and practice (Angeli & Valanides, 2009). Pre-service teachers will benefit from up-to-date technology tools and resources available for them in their preparation programs, especially if those tools come with adequate support in how to use them. It is important that these technology tools are not being presented separate from pedagogical activities but rather integrated within the context (AACTE, 2012). Lyublinskaya and Tournaki (2012) argue that in order to achieve a comfortable level of expertise to effectively use technology as a teaching tool, one needs “considerable education and experience” (p.300). To make important instructional decisions, teachers must rely on a well-developed and in-depth knowledge of student learning, of the content they are to teach, of the variety of the pedagogical activities that support students' learning, but they also need knowledge of multiple technologies that can be used as tools for learning (Niess, Kajder, & Lee, 2008). Specifically, Niess (2008) argues that teachers must have a well-developed Technological Pedagogical Content Knowledge (TPACK), the knowledge that teachers need for teaching with and about technology in their assigned subject areas and grade levels.

Teachers' Views and Beliefs on Using Technology in the Classroom

There are several reasons why technology integration in a teacher education program is not guaranteeing new teachers will use technology in their classrooms. Providing teachers with access to technology does not mean that they will use it. Many teachers believe that technology is not necessary for student learning, moreover it can be a source of distraction as opposed to a learning tool (Heick, 2016). A study was conducted to show that teacher beliefs about the practice of teaching are a significant determinant in explaining why teachers adopt computers in
the classroom (Hermans, Tondeur, van Braak, & Valcke, 2008). "Teachers attitude towards computer use and computer self-efficacy have enormous effect on behavioral intention to use technology, while perceived ease of use, and technological complexity, and facilitating conditions affect behavioral use indirectly" (Teo, 2009, p. 306).

Based on the literature review, teachers are divided in their views of importance of technology in learning. Some believe that there is a value in using technology in the classroom, however technology could fail and students instead of learning would be distracted (Lei, 2009). Others believe that computers should be used in moderation as students can easily start depending on them. Teachers use new technology mostly in old or basic ways that means to transmit information, monitor student progress, keep records, communicate with others, and conduct research on the Internet. The way teachers use technology depends often on the difficulty level of learning and on teachers’ abilities on using new technologies. Hermans et al., (2008) reported that pre-service teachers will choose the easiest and most familiar medium. On the other hand, many veteran teachers got used to certain ways of teaching and do not want or do not see the need to change their ways of teaching. It is because these teachers do not feel comfortable with the new technologies or they do not see the advantages in including technology to the present curriculum. Insufficient support, training and sharing of resources can also make teachers skeptical on using technology in their classrooms. Other reasons why teachers don’t use instructional technologies may be caused by personal factors like attitudes and beliefs, anxiety, self-efficacy, willingness to make a time commitment and face the risk involved with using technology, competency, perceptions of the technology's relevance, and lack of knowledge (Ertmer et al., 2012). Kim et al. (2013) argues that teachers are more likely to use technology in their classroom if they believe in the effectiveness of using technology, especially for student-
centered tasks. Teachers beliefs are influenced by their perceived value for the instructional use of that technology: the more likely the technology has a potential to help teachers to meet learning needs of their students, the more likely the teachers are to use that technology in their classrooms (Ottenbreit-Leftwich et al., 2010; Shifflet & Weilbacher, 2015). It is therefore crucial for schools of education to help pre-service and in-service teachers to become aware of the benefits of the appropriate use of technology to facilitate meaningful student learning (Ertmer and Ottenbreith-Leftwich, 2010).

**Technology in Special Education**

According to the data from the National Longitudinal Transition Study, 21% of students with special learning needs are five or more grade levels below in reading; 31% of students with disabilities drop out of schools compared to 9.4% of nondisabled peers, and only 11% of students with disabilities attend postsecondary institutions. According to the researchers, effective deployment and use of technology in schools could be the solution for helping to improve academic outcomes for students with special learning needs, and could help bridge educational gaps between American students (Keneddly & Deshler, 2010). With proper usage, educational technologies can: provide scaffolds for learning and promote innovative teaching methods e.g. cooperative learning (Roschelle et al., 2010) and exploratory learning outside the classroom (Liu, Lin, Tsai & Paas, 2012), make opportunities for two-way conversations between teachers and students (Day & Kroon, 2010), support reflection and revision (Quellmalz & Pellegrino, 2009), and support the development of intellectual tools and learning allowing students to become self-sustained, lifelong learners. Special educators must be aware of both
uses of technology: assistive and instructional to support the personalized learning, increase student’s independence and help improve academic skills of students with disabilities (www.nces.ed.gov).

**Assistive Technology (AT)**

IDEA (2004) defines assistive technology as "any items, pieces of equipment, or product systems that are used to increase, maintain, or improve the functional capabilities of individuals with disabilities". (sec. 300.5) These devices may include commercially available, modified or customized equipment (Osborne & Russo, 2007). The IDEA principle of least restrictive environment requires that the Individualized Education Program (IEP) team consider the child's placement in the general curriculum with the use of assistive devices as a first option within the continuum of services. The No Child Left Behind Act of 2002 supports IDEA in ensuring all students an equal access to education regardless of their abilities or disabilities. Kennedy and Deshler (2010) argue that assistive technology devices can help students with disabilities achieve at higher levels, better interact with their environment, communicate more effectively, and become more independent.

**Instructional Technology (IT)**

Instructional technology can be defined in two ways (Gagne, 2013), as the media and other technology used (e.g. audiovisual media, computer, SMART Board, document camera, calculator, blog, wiki, etc.) that can be used for instructional purposes and as a process: “It is a systematic way of designing, carrying out, and evaluating the total process of learning and teaching… to bring about more effective instruction” (p.12). Technology can be used to improve
the design and delivery of instructions. Instructional technology could be a potential equalizer for the struggling learner (Smith & Okolo, 2010). According to Starcic (2010) instructional technology plays a vital role in creating an effective and adaptable learning environment for teaching individuals with special needs in the general education environment. Studies suggest that students, specifically those with learning disabilities, greatly benefit from learning with technology (Allsop, Mc Hatton, & Farmer, 2010; Kennedy & Deshler, 2010), especially when technology is designed specifically for the needs of the learner (Starcic, 2010). Allsopp et al. (2009) examine the use of technology to enhance the academic outcomes of students who have learning disabilities in math and believe that technology integration can address disability-related learning barriers and enhance students' strengths to engage them in active learning.

Teaching practices that could be implemented through the use of technology include: drill and practice, simulations, discovery learning, presentations, videos, higher level discussion, critical thinking activities, peer assisted learning, communication access (through email, chats, blogs, wikis, video conferences, and other forms of social media outlets) and more (Chen, 2010). Teachers have opportunities to design a lesson that can complement the learning styles of all students. Including a variety of instructional strategies (e.g. audio, visual and tactile approaches) at various levels, allows teachers to provide diverse learning experience to their students including those with learning disabilities (Moeller & Reitzes, 2011). Using the groups and ability levels, teachers can create integrated curriculums that truly meet the needs of all students. Students can also benefit greatly from instructional technology due to: receiving immediate feedback, working individually on task - which leads to feeling sense of freedom and taking responsibility of their own learning, self-pacing, opportunities to revisit information, etc.
There is ongoing debate whether the technology can truly bridge the gap and support educational quality (Lim et al., 2013). There is a need for more studies addressing questions: e.g. how technology be integrated effectively, what educational goals and learning objectives will be accomplished by using technology in schools (p.65). Researchers agree that the way technology is used by teachers and students may make a difference, and with research, experimentation, teacher preparation and educator training, closing the achievement gap in special education is possible (Moeller & Reitze, 2011). Researchers raise question on how to prepare teachers to take advantage of technology to effectively support learning difficulties of their students. Teachers in the twenty-first century cannot teach as they were taught as so much changed with the integration of information technologies in everyday lives. Even though teachers may know how to use the technologies does not mean they know how to teach with technologies; they need strategies and proper preparation. Before integrating technologies as learning tools teachers need to think strategically whether the usage of these tools will truly enhance students’ learning. To make important instructional decisions, teachers must rely on a well-developed and in depth knowledge of student learning, of the content they are to teach, of the variety of the pedagogical activities that support students’ learning, but they also need knowledge of multiple technologies that can be used as tools for learning (Niess, 2008).

According to the recent studies, the TPACK framework used to redesign courses in teacher preparation programs may help new teachers acquire the knowledge and skills necessary to prepare them for effective technology integration into the classroom (Chai, Koh & Tsai, 2010; Tondeur et al., 2017).
Theoretical Framework

This dissertation is framed by the Technological Pedagogical and Content Knowledge (TPACK) framework.

**Technological Pedagogical Content Knowledge (TPACK)**

TPACK was developed as a conceptual framework for inclusion of technological knowledge into Shulman's (1986) framework of "Pedagogical Content Knowledge (PCK)".

Shulman (1986) proposed that teachers' content knowledge and pedagogy knowledge should not be treated as mutually exclusive domains (both in research and in practice), but rather as knowledge of the subject matter and pedagogical strategies - that he called PCK (the intersection of content and pedagogy). Shulman (1986) argued that having good knowledge of subject matter and knowledge of general pedagogical strategies is not sufficient for teacher to be effective. In order to prepare successful teachers, teacher preparation programs should focus on developing teachers' PCK, that represents the knowledge of how to "interpret the subject matter and find different ways to represent it and make it accessible to learners" (p.1021). Mishra and Koehler (2006) expanded Shulman’s framework by adding the knowledge of technology as a domain, since technology, especially the digital technology, have changed (or can change) the nature of the classroom.

Although the current technologies become quickly obsolete, the authors argue that the use of technology for pedagogy of specific subject matter could be expected to remain relatively static. Therefore, teachers need to learn techniques and skills that can be applied when using various current, and future technological tools. Since technological knowledge and skill set is often considered to be separate from pedagogical and content knowledge, many teacher
preparation programs offer technology courses that teach pre-service teachers skills needed to use specific tool, rather than teaching them how to apply these tools in the specific content and pedagogy.

**TPACK Construct.** TPACK (Technological Pedagogical Content Knowledge) as defined by Mishra and Koehler (2006) describes the nature of knowledge that is required by teachers to teach with technology while addressing the complex nature of teacher knowledge for specific subject areas (e.g. mathematics or science) and grade levels. TPACK is identified with teachers’ knowledge that relies on the intersection of curriculum content, pedagogy, and technology (see Figure 1.1). The TPACK framework includes seven domains (see Figure 1), that can be further classified as *basic domains*: TK – knowledge and proficiency with technology tools (Shinas et al., 2013), PK – knowledge of educational theories and instructional methodologies needed to develop appropriate instructions, and CK – knowledge of the subject matter; and *composite domains*: TCK – knowledge of using technology tools to support specific content matter, PCK – knowledge needed to develop and deliver effective content-specific instruction, TPK – knowledge of how technology can support teaching and learning, and TPACK – knowledge that supports teacher’s ability to integrate content, pedagogy and technology in a unique context (subject matter, grade-level, teachers, school factors, demographics, culture, learning environment, etc.).
In theory, both basic and secondary domains should act as “epistemic resources to support the teachers’ development of TPACK” (Dong et al., 2015, p.2). According to studies however, the level of teacher’s basic or composite domains of knowledge may (Chai et al., 2013; Kramarski, Hai, Koh, Tsai, & Tan, 2011) or may not (Kaplon-Schilis & Lyublinskaya, 2015) contribute to the final level of teacher’s TPACK. Some researchers argue that it may be difficult to distinguish the boundaries between different knowledge domains of the TPACK framework (Archambault & Barnett, 2010; Graham et al., 2012), and therefore it may be difficult to create instruments for measuring and assessing separate TPACK domains. In order to address the effectiveness of teacher education programs, TPACK constructs need to be precisely defined, and reliable instruments need to be created “for measuring and assessing TPACK in a variety of
context” (Shinas et al. 2013, p.340). More research is needed on the TPACK constructs and their effect on the TPACK.

**Progressive Levels of TPACK**

Niess et al. (2010) proposed developmental model for TPACK as the knowledge that teachers need to effectively integrate technology for teaching specific content area and grade level. Her developmental model of growth (see figure 1.2), adapted from the Rogers’ (1995) five-stage sequential model of the innovation-decision process to explain qualitative descriptors, shows five stages *(Recognizing, Accepting, Adapting, Exploring, and Advancing)* that teacher progresses through when learning to integrate technology in teaching and learning. When learning to integrate a particular technology teacher progresses through five-level developmental process: Level 1 *(Recognizing)* - Teachers do not integrate technology in teaching and learning, even though they are able to use technology and recognize the place of technology within specific content. Level 2 *(Accepting)* – Teachers form a positive or negative attitude towards teaching and learning with specific technology. Level 3 *(Adapting)* – Teachers decide to adopt or reject teaching and learning with an appropriate technology. Level 4 *(Exploring)* - Teachers integrate an appropriate technology for teaching and learning of the specific content. Level 5 *(Advancing)* – Teachers confirm and evaluate results of integrating an appropriate technology for teaching and learning of the specific content.
Niess (2008) identified four components of TPACK, adapted from Grossman’s four components of PCK (1989), and rephrased towards integrating technology in teaching: “1) an overarching conception of what it means to teach particular subject integrating technology with learning; 2) knowledge of instructional strategies and representations for teaching particular topics with technology, 3) knowledge of students’ understanding, thinking and learning with technology in a particular subject, 4) knowledge of curriculum and curriculum materials that integrate technology with learning in the subject area” (p.511).

Niess et al. (2010) developed a qualitative schema to measure the development of pre-service teachers’ TPACK in teaching mathematics through progressive levels. Lyublinskaya and Tournaki (2012) adapted Niess’ schema to develop the TPACK Levels Rubric to provide a
quantitative instrument for measuring teachers’ TPACK level based on teachers’ artifacts. The *TPACK Levels Rubric* instrument was used in all studies in this dissertation for external assessment of teachers’ TPACK (see Appendix A).

**Current Research on TPACK in Special Education**

Schools of Education should have available technology resources, appropriate curriculum, and authentic experiences in technology use to provide both theory and practice in their special education teacher preparation programs (Tondeur et al., 2012). When pre-service special education teachers are learning how to integrate technology into teaching and learning, the TPACK framework-based courses in teacher preparation may help them to acquire the knowledge and to develop appropriate skills necessary to prepare them for effective technology integration to address the needs of all their students (Tondeur et al., 2017).

There is limited research on integrating the TPACK framework in teacher preparation programs for special education teachers. Most reported cases of using the TPACK framework to redesign teacher preparation programs have been applied to programs preparing general education teachers. The current research includes theoretical papers suggesting various TPACK models (Marino, Sameshima, & Beecher, 2009; Bento-Borghi, 2013) and empirical studies examining development of TPACK in pre-service elementary special education teachers (Lyublinskaya & Tournaki, 2014; Kaplon-Schilis & Lyublinskaya, 2015; Tournaki & Lyublinskaya, 2015). Marino et al. (2009) suggested that including assistive technology and instructional technology as two overlapping constructs in the extended TPACK model would improve learning outcomes for all students, including students with disabilities. Benton-Borghi
(2013) recommended the blended TPACK model with the UDL infusion as the way to support understanding of “teaching and student learning in a collaborative, inclusive, equitable, and less divided system of education” (p.255). The empirical studies include examination of TPACK developments of pre-service special education teachers using instructional technologies (Lyublinskaya & Tournaki 2014), and the investigation whether the TPACK-based course affects basic domains of pre-service special education elementary teachers’ (Kaplon-Schilis & Lyublinskaya, 2015). Tournaki and Lyublinskaya (2015) in their paper, argue that the TPACK framework can be used to “develop excellence in teaching in a variety of classrooms, which includes differentiation of instruction” (p. 3004).

As pre-service teachers develop TPACK in teacher education programs, they are expected to transfer their knowledge and skills into their future classrooms, however there is very limited research that examines how specific courses focusing on development of TPACK influence preservice teachers’ use of technology once they graduate (Scheeler, 2008). In order to increase pre-service teachers’ knowledge transfer, researchers suggest to allow sufficient instructional time to develop concepts and procedure (Alexander, 2006), and to increase the authentic or performance-based tasks and assessment (Darling-Hammond & Bransford, 2007). De Jong et al. (2010) suggest that Group-Based Learning (GBL) as a teaching strategy in preservice pedagogy courses promotes pre-service teachers’ effective transfer of knowledge. Dickenson (2017) recommends that in order to promote transfer of preservice special education knowledge from theory to practice, the Universal Design for Learning (UDL) principles and guidelines can be integrated through course content. Embedding the three UDL principles: into preservice pedagogy course supports assisting preservice teachers in designing lesson plans and activities for all students in inclusive classroom (CAST, 2011). Israel, Ribuffo and Smith. (2014)
provides application of the three UDL principles in a science classroom to support learning of all students with technology: (1) Representation: using a variety of materials, visual scaffolds, audio, video, animations, interactive webs, embedded supports to contextualize the content for the learner; (2) Action and Expression: using presentations, multimedia to provide opportunities for student to demonstrate understanding in an appropriate manner, and (3) Engagement: interactive mages and active learning to promote engagement and interaction with the instruction process.

Understanding how teachers transfer their learning from the teacher preparation course to their teaching practice is crucial, however there is limited research on how preservice teachers transfer their TPACK.

Despite growing interest in the TPACK framework, there are few studies that focus on using the TPACK framework with special education teacher preparation. There is a need for more research to investigate TPACK in special education. There is a need to define constructs, to understand instruments that are used to measure special education teachers’ level of TPACK. Although there are separate studies that focus on measuring pre-service teachers’ and in-service teachers’ TPACK, there is no research that follows pre-service teachers after they graduate, and investigate what happens with their TPACK. The purpose of this dissertation is to address some of the existing gaps in the current studies that investigate TPACK development and transfer for special education elementary school teachers.
Special Education Pre-service and In-service Teacher’s TPACK

The research completed for this dissertation addressed some of the existing gaps in the current literature that investigate the development and transfer of TPACK of pre-service and in-service elementary school special education teachers (see figure 1.3). The purpose of this dissertation is to 1) analyze TPACK that special education elementary school teachers gain during their graduate level work in a course that specifically focuses on preparing them to use technology for teaching mathematics and science, 2) assess TPACK of the same teachers as they implement technology into teaching mathematics and science in their elementary classrooms during their first year of teaching, 3) analyze whether the TPACK-based course affects TPACK and basic TPACK domains of pre-service special education teachers’ knowledge: TK – technological knowledge, PK- pedagogical knowledge, and CK – content knowledge, and 4) explore what happens with the pre-service teacher’s TPACK as she continues her professional practice. The dissertation consists of three studies conducted with pre-service and in-service elementary special education teachers. These studies were guided by the following research questions:

1. Does the pedagogy course designed around the TPACK framework affect the basic domains of special education elementary pre-service teacher knowledge, i.e. TK (Technological Knowledge), PK (Pedagogical Knowledge), CK (Content Knowledge) in mathematics and science? (Chapter 2)

2. Does the TPACK-based graduate pedagogy course have an effect on pre-service special education teachers' TPACK (Technological Pedagogical Content Knowledge) in mathematics and science? (Chapter 2)
3. Is there a relationship between basic domains of the TPACK framework - TK, PK, and CK - and the TPACK domain of preservice special education elementary school teachers? (Chapter 3)

4. What instructional strategies and experiences in the graduate pedagogy course supported TPACK development of this pre-service teacher? (chapter 4)

5. What are the internal and external factors affecting TPACK transfer for this teacher? (chapter 4).

More research is needed to understand relationships between different domains of TPACK framework. Chapter 3 analyzes whether TK (Technological Knowledge), PK (Pedagogical Knowledge) and CK (Content Knowledge), three of the domains of the TPACK framework, contribute into the TPACK domain. While studying the relationship between basic domains of teacher knowledge of pre-service special education teachers, the author also investigates whether pre-service teachers gain TK, PK, CK, and TPACK in the pedagogy graduate level course (chapter 2). Chapter 4 presents a case study to investigate whether pre-service teacher’s TPACK developed during the graduate level course, transfers into her classroom practice. All of the studies in this dissertation use the same instrument for measuring teachers’ TPACK: *TPACK Levels Rubric* (Lyublinskaya & Tournaki, 2012).
Figure 1. 3 Concept Map
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CHAPTER 2. EXPLORING CHANGES IN TECHNOLOGICAL KNOWLEDGE (TK), PEDAGOGICAL KNOWLEDGE (PK), CONTENT KNOWLEDGE (CK) AND TPACK OF PRE-SERVICE, SPECIAL EDUCATION TEACHERS TAKING TECHNOLOGY-BASED PEDAGOGICAL COURSE.

A paper submitted to the Contemporary Issues in Technology and Teacher Education Journal

ABSTRACT

This paper presents findings of a long-term study conducted with pre-service special education elementary teachers taking the graduate level course Integrating Technology in Mathematics and Science Instruction in Special Education and Inclusive Classrooms in a New York City public college. The purpose of this single group pre- post-test study was to analyze a) whether the TPACK (Technological Pedagogical and Content Knowledge) -based course affects basic domains of pre-service special education elementary teachers' knowledge: TK - technological knowledge, PK - pedagogical knowledge, and CK - content knowledge in Math and Science, and b) how does the course affect teachers' TPACK domain. The paired sample t-test indicated significant gains in teachers' TPACK, however, there were no significant changes in PK, TK, and CK. These results suggest that effectively designed TPACK-based course could significantly improve contextual TPACK domain. However, the study raised question on whether the basic domains of the TPACK framework are independent of TPACK domain.
Instructional technology, when used appropriately and strategically can provide access to learning for all students. The Individuals with Disabilities Education Act (2004) advocated improvements in the use of technology within the Universal Design for Learning (UDL) framework for students with disabilities. The 2015 National Assessment of Educational Progress (NAEP) presented the data of the math performance scores in the U.S. Although only 18% of grade 4, and 29% of grade 8 students scored below the basic level, the numbers for students with disabilities (45% - 4th grade, 68% - 8th grade are below basic math level) and students learning English language (43% - 4th grade, 69% - 8th grade) showed more disparities. One way to decrease the gap between the general education learners and students with special learning needs is to address the various cognitive strengths and needs of all students (Luster, 2008). All special education students have similar learning needs (reading, writing, etc.) Additional needs vary based on specific disabilities. Teachers must consider the needs of diverse learners and be equipped to support their learning needs by taking advantage of technology. According to Altan (2013) the main reason for including technology in special education is to assist students with their physical needs (assistive technology) and/or students’ instructional needs (instructional technology).

Students with special needs usually struggle with problem solving, especially in identifying and selecting appropriate strategies, organizing information, monitoring problem-solving processes, and generalizing strategies to new situations. Very often, students with special needs receive more direct instruction practices without opportunities to extend critical-thinking level. However, research shows that these students can develop mathematical understandings beyond simple rote repetition of algorithms and procedures (Niess, 2008). The virtual
manipulatives, and interactive activities with guiding questions and kid-friendly instructions and vocabulary can help overcome some of these limitations. Using technology in the classroom (mobile technologies, computers, educational software, games etc.) can support learning skills including language, mathematics, science, environmental awareness, autonomy and social skills for students with special learning needs (Fernandez-Lopez et al., 2013).

Therefore, it is extremely important that technology is used in the classroom to enhance learning and to prepare students for 21st century skills, but many teachers do not find specific technology skills they have learned in pre-service teacher education programs meaningful or relevant to their teaching practices (Ottenbreit-Leftwich et al., 2012; Nelson, Palonsky & McCarthy, 2000). Studies show that in most teacher education programs pre-service teachers do not have prior experience of content learning with digital technology. They need specialized instruction on how to teach their content with technology while simultaneously guiding students in learning about new forms of technology (Niess, 2008).

**Preparing Pre-Service Teachers to Use Technology**

Since the introduction of educational technologies into classroom settings, teacher education has faced the challenge of improving in-service teacher education and preparing pre-service teachers for successful integration of educational technologies into their teaching and learning practices (Sang et al., 2009). Teacher educators have acknowledged the need for the specific technology training in pre-service programs; yet some research shows a lack of quality programs in Colleges of Education (Fleming, Motamedi & May, 2007). Lyublinskaya and Tournaki (2012) argue that in order to achieve a comfortable level of expertise to effectively use technology as a teaching tool, one needs “considerable education and experience” (p. 297). Some
colleges offer extensive training with technology, moreover they require future teachers to pass technology competency tests before graduating their program (e.g. Hunter College, City University of New York, http://www.hunter.cuny.edu/). Others do not put such an emphasis on introducing and modeling the use of technology to the future teachers, and the only hope of learning how to implement new programs in teaching lies in professional development that teachers could get involved when they start full time teaching. Pre-service teachers will benefit from up-to-date technology tools and resources, available for them in their preparation programs, especially if those tools come with adequate support in how to use them. It is important that those technology tools are not being presented separate from pedagogical activities but rather deeply integrated within them (AACTE). Modeling how to use technology in education is crucial for future teachers. As one suggestion on how to improve teacher preparation program, American Association of Colleges for Teacher Education (2012) recommends that curricula of these programs should be aligned with student and teacher standards in ways that blend thinking and innovation skills, ICT literacy; and life and career skills in the context of all academic subject and across interdisciplinary themes.

Since the quantity and quality of pre-service technology experience provided and used in teacher education programs highly influences new teachers' implementation of technology in their classrooms (Agyei & Voogt, 2011), it is critical to provide pre-service teachers with learning opportunities that are as similar to actual K-12 classroom practice as possible: (1) the training of the technology skills within an educational context, (2) opportunities for "hands-on" practice, and (3) the training consistent with specific and authentic needs faced by teachers in their daily work (Chien et al., 2012; Ottenbreit-Leftwich et al., 2012). Seeing technology, pedagogy, and content as being independent from each other is a common problem in pre-service
training. The need for a successful integration of technology, pedagogy, and disciplinary content in teacher education programs is undeniable. Given the lack of good role models that pre-service teachers encounter (Tearle & Golder, 2008), researchers have recommended that technology should be integrated throughout the curriculum in order to provide pre-service teachers with the experiences needed to apply technology to their specific content areas (Ottenbreit-Leftwich et al., 2012). The pre-service teachers in these interventions indicated that they felt additional planning and preparation was needed to implement lessons incorporating technology. There is a need for courses that integrate the teaching of all the components of teacher knowledge: disciplinary content knowledge, pedagogy skills, and technology skills (Mishra & Koehler, 2006). To make important instructional decisions, teachers must rely on a well-developed and in-depth knowledge of students learning, of the disciplinary content they are to teach, of the variety of the pedagogical activities that support students’ learning, but also knowledge of multiple technologies that can be used as tools for learning (Niess, 2008).

The TPACK framework can provide a conceptual framework for developing courses that would integrate the teaching of all the domains of teacher knowledge: content (subject matter), pedagogy (teaching and student learning) and technology (Mishra & Koehler, 2006; Niess, 2005; Lyublinskaya & Tournaki, 2011). However, as a framework TPACK does not specifically provide guidelines on what learning experiences are needed by pre-service teachers in order for their TPACK development. (Niess, 2012). Helping pre-service teachers to gain TPACK knowledge becomes mostly the responsibility of the teacher education program.
TPACK Framework

The TPACK framework was developed in response to the need to prepare teachers to use technologies designed for the classroom. Mishra and Koehler (2006) built upon Shulman’s (1986) idea of PCK (Pedagogical Content Knowledge) framework by adding TK (knowledge of technology) to create TPACK. TPACK domain of the framework is identified with knowledge that teachers need for teaching with technology in their specific content areas and grade levels (Niess, 2008). TPACK framework describes seven knowledge domains (see Figure 2.1) needed for effective integration of technology in the classroom: TK – knowledge and proficiency with technology tools (Shinas et al., 2013 ), CK – knowledge of the subject matter, PK - knowledge of educational theories and instructional methodologies needed to develop appropriate instructions, TCK – knowledge of using technology tools to support specific content matter, PCK – knowledge needed to develop and deliver effective content- specific instruction, TPK – knowledge of how technology can support teaching and learning, TPACK – knowledge that supports teacher’s ability to integrate content, pedagogy and technology in a specific context (subject matter, learning environment, etc.).
In order to use the TPACK framework in technology integration, schools of education should have available technology resources, appropriate curriculum, and authentic experiences on how to use technology to provide both theory and practice into special education teacher education (Tondeur et al., 2012). When pre-service teachers are learning how to integrate technology into special education, the TPACK framework may provide a systematic and meaningful way to develop appropriate skills for technology integration to address the needs of all students, including those with disabilities.

**Technology in Special Education**

According to the data from the National Longitudinal Transition Study, 21% of students with special learning needs are five or more grade levels below in reading; 31% of students with disabilities drop out of schools compared to 9.4% of nondisabled peers, and only 11% of
students with disabilities attend postsecondary institutions. Fortunately, technology could be the solution for helping to improve academic outcomes for students with special learning needs (Kennedy & Deshler, 2010).

**Assistive Technology (AT).** According to the Individuals with Disabilities Education Act Amendments (IDEA) of 2004. An assistive technology refers to "any items, pieces of equipment, or product systems that are used to increase, maintain, or improve the functional capabilities of individuals with disabilities" (SEC 602[1]). These devices may include commercially available, modified or customized equipment (Osborne & Russo, 2014). The IDEA principle of least restrictive environment requires that the IEP team consider the child's placement in the general curriculum with the use of assistive devices as a first option within the continuum of services. The No Child Left Behind Act of 2002 support IDEA in ensuring all students an equal access to education regardless of their abilities or disabilities. Kennedy and Deshler (2010) argue that assistive technology devices can help students with disabilities achieve at higher levels, better interact with their environment, communicate more effectively, and become more independent.

**Instructional Technology (IT).** Instructional technology could be a potential equalizer for the struggling learners (Smith & Okolo, 2010). For these students, technology can assist in increasing independence, but also inclusion and participation in classroom activities. According to Starcic (2010) instructional technology plays a vital role in creating an effective and adaptable learning environment for teaching individuals with special needs in the general education environment. Studies suggest that students, specifically those with learning disabilities greatly
benefit from learning with technology (Allsopp, Mc Hatton, & Farmer, 2010) especially when technology is designed specifically for the needs of the learner (Starcic, 2010).

Allsopp et al. (2009) examines the use of technology to enhance the academic outcomes of students who have learning disabilities in mathematics. Researchers argue that in order for technology to be a useful tool for educating students with disabilities, instructional technology has to be matched with evidenced based practices based on the needs of students (e.g. activation of prior knowledge through the use of digital photos, calculators can help students who have difficulties with recall and retrieval, etc.). Researchers believe that technology integration can address disability related learning barriers and enhance students' strengths to engage them in active learning.

Teaching practices that could be implemented through the use of technology include: drill and practice, simulations, discovery learning, presentations, videos, higher level discussion, critical thinking activities, peer assisted learning, communication access (through email, chats, blogs, wikis, video conferences, and other forms of social media outlets) and more. Teachers have more opportunities to design a lesson that can complement the learning styles of all students. Differentiation of the instruction becomes much easier. Using the groups and ability levels, teachers can create integrated curriculums that truly meet the needs of all students. Students can also benefit greatly from instructional technology due to: receiving immediate feedback, working individually on task - which leads to feeling sense of freedom and taking responsibility of their own learning, self-pacing, opportunities to revisit information, etc. With access to simple technology, a student with learning disabilities can have the same access to the general curriculum as his non-disabled peers without being limited by his disability.
TPACK in Special Education

There is insufficient research on integrating TPACK into pre-service teachers’ preparation, especially in using TPACK in special classrooms (Altan, 2013). Integrating TPACK into pre-service special education may affect pre-service teachers’ attitudes towards using technology in class, especially if pre-service teachers experience appropriate technology for a specific pedagogy and content. Research revealed the positive effect on pre-service teachers' self-perceptions and knowledge on instructional technology abilities when technology courses were integrated into pre-service teacher education in special education curriculum (Allsopp, McHatton & Cranston-Gingras, 2009). In another study with pre-service teachers, the researchers used the TPACK framework as a lens for understanding technology-integration decisions (Graham, Borup, & Smith, 2012). The researchers analyzed pre-service teachers’ rationales for decisions regarding using technology in teaching and found significant growth in several TPACK domains. Further, a study by Anderson, Griffith, and Crawford (2014), revealed that using TPACK as a framework for the pre-service teacher course on how to integrate iPad APPs into planning and implementing effective technology-integrated lessons was beneficial to both pre-service teachers and the students with mild disabilities.

There is not much research on integrating the TPACK framework for special education teacher education. Most of all reported cases of using the TPACK framework to redesign teacher preparation programs have been applied to programs preparing general education teachers. The recent research includes theoretical papers suggesting various TPACK models (Marino, Sameshima & Beecher, 2009; Benton-Borghi, 2013). Marino et al. (2009) suggested that including assistive technology and instructional technology as two overlapping constructs in the extended TPACK model would improve learning outcomes for all students, including students
with disabilities. Benton-Borghi (2013) recommended the blended TPACK model with the UDL (Universal Design for Learning) infusion as a way to support understanding of “teaching and student learning in a collaborative, inclusive, equitable, and less divided system of education” (p.255). Courduff et al. (2016) argues that technology integration by special education preservice teachers is very complex and suggests that TPACK model should be expanded by the technology acceptance model (TAM). Pre-service special education teachers’ knowledge (TPACK) is insufficient “in effective implementation of technology…dispositions and beliefs were foundational to the application of skill and knowledge to instructional practice” (Courduff et al., 2016, p.36). The empirical studies include examination of TPACK developments of pre-service special education teachers using instructional technologies (Lyublinskaya & Tournaki, 2013, Tournaki & Lyublinskaya, 2014). There is a need for more research for integrating TPACK into special education teacher education.

**Research Questions**

This study was guided by the following research questions:

1. Does the pedagogy course designed around the TPACK framework affect the basic domains of special education elementary pre-service teacher knowledge, i.e. TK (Technological Knowledge), PK (Pedagogical Knowledge), CK (Content Knowledge) in mathematics and science?

2. Does the TPACK-based graduate pedagogy course have an effect on pre-service special education teachers' TPACK (Technological Pedagogical Content Knowledge) in mathematics and science?
The Study Context

The study was conducted in the context of a graduate pre-service elementary special education teacher program in a New York public university. The purpose of this study was to analyze whether the graduate-level course *Integrating Technology in Math and Science Instruction in Special Education and Inclusive Classrooms* affected TK, PK, and CK and TPACK of pre-service special education elementary teachers. The objective of the course was to develop pre-service elementary special education teachers' TPACK for teaching mathematics and science to students with special needs. Collection of data started in the Spring 2014 semester; and continued through the Spring 2016 semester.

The course met weekly for 15 two-hour sessions and one-hour lab session in a computer laboratory to facilitate easy access to technology; all sections had the same instructor, they used the same syllabus and course activities. Within the course, pre-service teachers examined the use of traditional and emerging instructional technologies that are necessary to foster inquiry, enhance learning and reduce the achievement gap for students with special needs. Pre-service teachers learned how to use various digital tools (e.g. Microsoft Office – advanced features of Word, PowerPoint, Excel, SMART Board and SMART Notebook software, Geometer’s Sketchpad- dynamic geometry software for teaching and learning mathematics in grades 3-12, Data Collection – sensors/probes, calculators, Web 2.0 tools such as blogs, etc.) in elementary mathematics and science classroom. Within the course, pre-service teachers begun understanding what role digital technology can play in teaching and learning mathematics and science in inclusion classrooms. Pre-service teachers used specific instructional technology tools to develop
mathematics or science activities, and lesson plans that could be used by all students including those with special needs. Pre-service teachers learned how to differentiate instruction with technology, how to assess their students' learning using technology, how to use the technology to adapt their instructions for learners with special needs and how to engage and include all type of learners within their classes while using various instructional technologies. TPACK framework was introduced to all participants and used as a guide in completing course assignments. Within the course, pre-service teachers developed and taught two lessons, one in mathematics and one in science, videotaped them, and then reflected on their teaching experience using the principles of the effective use of technology (Goldenberg, 2000). Table 2.1 provides an example of course assignments (see Table 2.1).

Methods and Instruments

The study followed causal-comparative pre-post single-group design. The data was collected at the beginning and at the end of the semester using the following instruments: (1) TKT - Technology Knowledge Test - 30 minutes - 51 multiple-choice questions, measuring the basic level of technology literacy, test was adapted from the course's textbook (O'Bannon & Puckett, 2010), (2) PKT - Pedagogy Knowledge Test - 30 minutes 18 multiple-choice questions measuring the basic level of pedagogy knowledge, test was adapted from the NYSTCE practice ATS-W test (Elementary Assessment of Teaching Skills, http://www.nystce.nesinc.com), (3) CKMT – Mathematics Content Knowledge - 30 minutes 34 multiple choice and short response questions measuring basic level of math knowledge, (4) CKST - Science Content Knowledge Test - 30 minutes 25 multiple choice and short answers questions measuring basic level of
science knowledge, both CKMT and CKST adapted from NAEP Grade 4 test (http://nces.ed.gov/nationsreportcard/), (5) TPACK Levels Rubric - measuring teachers' Technological Pedagogical and Content Knowledge level based on lesson plans developed by pre-service teachers. TPACK Levels Rubric was developed and validated by Lyublinskaya and Tournaki (2012). TPACK rubric was based on the TPACK framework for teacher growth for technology integration in the classroom through 5 progressive levels [Recognizing (1), Accepting (2), Adapting (3), Exploring (4), to Advancing (5)] in each of the four components of TPACK (Conception, Students, Curriculum, and Instruction) (Niess, 2008).

The pre-tests for measuring TK, PK, and CK (CKM – content knowledge in math, CKS – content knowledge in science) were administered during the first two weeks of the course (see Table 2.2). TKT and PKT tests were taken online during lab hours, while both CKMT and CKST tests were given to pre-service teachers during the first course meeting. The first lesson plan was collected during the fifth (out of 15) week of classes, after participants were introduced to different models and strategies for technology-infused lessons, and learned the principles of effective use of technology (Goldenberg, 2000). The second lesson plan was collected during the 13th (out of 15) week of the class. Between 5th and 13th weeks pre-service teachers learned about different roles instructional and assistive technology plays in the inclusion settings, while also learning how to use the advanced features of Microsoft Word, PowerPoint, Excel, SMART Board and SMART Notebook software, Geometer’s Sketchpad, Data Collection tools (sensors/probes), calculators, and Web 2.0 tools (blogs) to develop various technology-infused activities, adapted and differentiated for learners with special needs. The post-tests for TK, PK, and CK were administered during the last two weeks of the classes.
Table 2. 1 *Sample Course Assignments*

<table>
<thead>
<tr>
<th>Assignment</th>
<th>Technology</th>
<th>Description</th>
<th>Application to Special Education</th>
</tr>
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</table>
| Multimedia Tutorial         | MS PowerPoint  | Interactive slideshow tutorial with non-linear design to support students learning of elementary math or science topics. Slides provides directions on how to use tutorial, including explanation of navigation buttons, interactive menu, topic content, summary, quiz, and additional resources. Tutorial provides visual representation, and information that students can use to meet the learning objectives. Interactive quiz should promote students’ ability to apply what they learned in the tutorial. | • Facilitating students independent learning at student’s own pace  
• Nonlinear structure, easy navigation, self-assessment with immediate feedback.  
• Using visual resources                                                                 |
| Exploratory Tool – Interactive Spreadsheet | MS Excel       | An interactive spreadsheet that has both inquiry-based activity and corresponding self-assessment. Teachers learn how to use advanced features of Excel software to create a worksheet that serves as practice (interactive, instructional tools that could be manipulated and explored by students), assessment (gives immediate feedback to students). Some of the topics of these tools done by pre-service teachers were: how to count money, how to compare fractions, how to measure length, characteristics of geometric shapes, etc. | • Facilitating students’ higher-order thinking  
• Providing immediate feedback and allowing self-assessment (built-in adaptation)  
• Providing students with exploration of patterns, and development of algorithms, allowing generalization  
• Allowing students to manipulate learning objects, provides multiple representations |
Table 2. *Course Structure*

<table>
<thead>
<tr>
<th>Week</th>
<th>Instructions</th>
<th>Data Collection</th>
</tr>
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<tbody>
<tr>
<td>1-2</td>
<td>Models and strategies for technology-infused lesson</td>
<td>TKT, PKT, CKMT, CKST</td>
</tr>
<tr>
<td>3-4</td>
<td>Principles of effective use of technology (Goldenberg, 2000) Role of the internet</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Using Visual Learning Tools</td>
<td>Lesson Plan 1 (TPACK)</td>
</tr>
<tr>
<td>6-12</td>
<td>Developing various technology-infused activities (adapted and differentiated for all learners) using advanced features of: Microsoft Word, PowerPoint, Excel, SmartBoard, Smart Notebook, Geometer's Sketchpad, Data Collection Tools, Calculators, Web 2.0</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Assessing students using technology</td>
<td>Lesson Plan 2 (TPACK)</td>
</tr>
<tr>
<td>14-15</td>
<td>Reflective teaching- importance of self-reflection</td>
<td>TKT, PKT, CKMT, CKST</td>
</tr>
</tbody>
</table>

**Participants**

Data was collected for 4 consecutive semesters: from students enrolled in a Master's program in Special Education at a New York City public university. Total of 116 participants agreed to participate in the study. Males comprised 7% of the group and females 93%. 39% of participants held a childhood teaching license, 15% an early childhood license, 3% a special education childhood license, 3% a special education adolescent license, and 40% did not have teaching license.
Findings

Analysis of TK, PK, and CK scores on pre- and post-tests

The paired samples $t$-test for PK, TK, CKM, CKS was used to compare post-test to pre-tests scores (see Table 2.3). The increase in TK and CKM scores were significant with moderate effect size. However, there was no significant difference between pre- and post-test scores for PK and CKS.

Table 2. 3 Descriptive Statistics and Paired Samples $t$-test Results for Basic Components of TPACK.

<table>
<thead>
<tr>
<th>Component</th>
<th>Pretest</th>
<th>Posttest</th>
<th>95% CI for Mean Difference</th>
<th>t</th>
<th>Cohen’s $d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PK (Pedagogical Knowledge)</td>
<td>60.70</td>
<td>59.03</td>
<td>-1.13, 4.49</td>
<td>1.185</td>
<td>0.11</td>
</tr>
<tr>
<td>TK Technological Knowledge</td>
<td>68.10</td>
<td>70.99</td>
<td>-4.28, -1.50</td>
<td>-4.12**</td>
<td>0.34</td>
</tr>
<tr>
<td>CKM (Math Content Knowledge)</td>
<td>70.67</td>
<td>80.27</td>
<td>-12.08, -7.13</td>
<td>-7.68**</td>
<td>0.64</td>
</tr>
<tr>
<td>CKS (Science Content Knowledge)</td>
<td>72.56</td>
<td>72.66</td>
<td>-2.50, 2.31</td>
<td>-0.08</td>
<td>0.01</td>
</tr>
</tbody>
</table>

* $p < .05$, ** $p < .001$.

Analysis of TPACK scores on the lesson plans

The paired samples $t$-test revealed that pre-service teachers' scores significantly improved from the first to the second lesson plan in each TPACK component (Conception, Students, Curriculum, and Instruction) and total TPACK. For all TPACK components the scores went from Accepting (2/5) to Adapting (3/5) level with large effect sizes (see Table 2.4).
The total TPACK mean score for the first lesson plan was 2.08 (SD = 0.97) indicating that after four weeks of instruction participants just achieved the second level of TPACK, that of Accepting (2/5) (see Table 2.4). The total TPACK mean score for the second lesson plan was 2.82 (SD = 0.89) indicating that participants remained at the same TPACK level - Accepting (2/5), but majority completed at least one performance indicator at the Adapting (3/5) level. Since total TPACK is determined by the lowest score across all four components, it represents a conservative measure of TPACK level and naturally does not increase as much as individual components. The paired samples t - test revealed that this gain was significant with large effect size ($t(45) = -4.395, p < 0.001$).

Table 2.4 Descriptive Statistics and Paired Samples Results for t-test for All Components and total TPACK

<table>
<thead>
<tr>
<th>Components</th>
<th>Lesson Plan 1</th>
<th></th>
<th>Lesson Plan 2</th>
<th></th>
<th>95% CI for Mean Difference</th>
<th>t</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conception</td>
<td>2.30</td>
<td>0.89</td>
<td>3.14</td>
<td>0.76</td>
<td>-1.03, -0.66</td>
<td>-9.04**</td>
<td>1.01</td>
</tr>
<tr>
<td>Students</td>
<td>2.25</td>
<td>0.81</td>
<td>3.02</td>
<td>0.67</td>
<td>-0.94, -0.60</td>
<td>-8.95**</td>
<td>1.04</td>
</tr>
<tr>
<td>Curriculum</td>
<td>2.52</td>
<td>0.80</td>
<td>3.10</td>
<td>0.64</td>
<td>-0.75, -0.42</td>
<td>-6.96**</td>
<td>0.80</td>
</tr>
<tr>
<td>Instruction</td>
<td>2.34</td>
<td>0.92</td>
<td>3.13</td>
<td>0.69</td>
<td>-0.99, -0.59</td>
<td>-7.99**</td>
<td>0.97</td>
</tr>
<tr>
<td><strong>Total TPACK</strong></td>
<td><strong>2.10</strong></td>
<td><strong>0.83</strong></td>
<td><strong>2.91</strong></td>
<td><strong>0.72</strong></td>
<td><strong>-0.99, -0.64</strong></td>
<td><strong>-9.17</strong></td>
<td><strong>1.04</strong></td>
</tr>
</tbody>
</table>

* $p < .05$, ** $p < .001$.

Discussion

The purpose of this study was to explore whether the basic domains of the pre-service elementary special education teachers' knowledge within TPACK Framework, e.g. TK, PK, and CK (in math and science) were affected by the TPACK-based graduate-level pedagogy course.
The purpose of this course was to introduce pre-service elementary teachers to technologies available for use in different types of classrooms along with teaching and learning practices that combine these technologies with subject specific content and pedagogies essential to special needs learners. During fifteen weeks, participants learned a variety of ways in which technology can be used to support learning mathematics and science for all students. The course specific focus was on development of pre-service teachers TPACK in teaching mathematics and science to students with special needs in elementary schools. The study examined the changes in the basic domains of knowledge, such as TK, PK, and CK (in math and science), which were not the focus of the course and the TPACK construct, which was the focus of the course.

According to the results pre-service teachers did not have significant changes in PK, and CKS, and their TK, and CKM scores significantly increased over the period of the course. Pre-service teachers also had significant gains in TPACK scores.

**TK (Technological Knowledge)**

Since the course did not address the technology literacy broadly but rather presented specific instructional methods for using few technology tools as a support for students with special needs, the increase in TK (from 68% on pre-test to 70% on post-test) was not very high and had moderate practical significance. This change could be explained by the fact that the pre-service teachers learned instructional strategies for using technology to enhance teaching and learning experience, along with skills on how to use few different types of technology. Findings show that pre-service elementary teachers came to the course with relatively basic knowledge of technology (average score on the initial test was 68%). The course introduced specific instructional methods for using technology tools as a support for students with special needs.
Participants learned strategies for using technology to enhance curriculum, rather than learning basic skills on how to use different types of technology (measured by the TK). For example, during the course pre-service teachers were taught how to use advanced features of specific software (e.g. Excel) to create interactive activities for their students. These experiences could have attributed to slight increase in TK.

**CK (Content Knowledge)**

The average mathematics scores (CKM) changed from 70% to 80%. The average science scores (CKS) stayed about the same at 72%. Content knowledge (CK) was not specifically targeted in this course; pre-service teachers were not taught mathematics or science. While developing mathematics or science activities and lesson plans for all types of learners, pre-service teachers chose topics for mathematics and science based on their comfort level. The findings confirm that pre-service elementary school teachers frequently lack mathematical and scientific knowledge related to the concepts that they teach (Matthews et al., 2010). Initially scores on the science part of the test were about the same as on the mathematics part of test. However, by the end of the course the scores on the mathematics part of the test significantly increased, while science test scores remained the same (80.9% on the mathematics post-test compared to 72.6% on the science post-test). The difference between mathematics and science test scores may indicate the common perception that elementary teachers have to teach mathematics daily, but do not have to teach science. This perception is typical for New York City public school teachers, as many New York City elementary schools now have specialized cluster teachers who teach science, while classroom teachers only focus on mathematics and literacy). Since CK was not specifically targeted in this course; we believe that the significant
gains in the pre-service teachers’ mathematics scores were result of external factors that need to be investigated further.

**PK (Pedagogical Knowledge)**

The results showed no significant change in the average PK scores form pre- to post-test. The PK test assessed basic pedagogical literacy using a range of topics (knowledge of instructional strategies, classroom management, etc.), not covered in this graduate course. The goal of this course was to build understanding of teaching and learning with technology based on pedagogical knowledge that preservice teachers should have gained in their mathematics and science methods courses. The course therefore did not focus on development of basic pedagogical knowledge assessed by the PK test. Even though the scores on the PK tests were very low (60%), they are representative of the state requirements for minimum passing score on the corresponding state certification test ATS – W. The scores on ATS – W state test range from 100 to 300 with the score of 220 representing the minimum passing score (www.nationreportcard.gov).

**TPACK (Technological Pedagogical and Content Knowledge)**

Development of TPACK was the primary focus of the course, which was designed around TPACK framework (Mishra & Koehler, 2006). TPACK describes the nature of knowledge that is required by teachers to teach with technology while addressing the complex nature of teacher knowledge for specific subject areas (such as mathematics and science) and within specific context (http://tpack.org). Since the objective of the course was to increase pre-
service elementary special education teachers' TPACK, the analysis of the collected data showed that the objective of the course was met.

All pre-service teachers had made varying degrees of progress in the development of their TPACK, and the average scores, of all TPACK components, showed that participants progressed from *Accepting* level (2/5) to *Adapting* level (3/5) after taking 15-week long course. Participants learned how to use instructional technology to enhance students learning. Still, on this level, “technology is used as a replacement for non-technology tasks”, mainly by teacher and "digital materials do not necessary promote students' reflections" (Lyublinskaya & Tournaki, 2013, p. 5010). At the *Adapting* level, teachers begin to identify ways to use technology in their lessons to save time or make procedures simpler. However, implementation of technology is integrative rather than transformative (Vandeyar, 2017). Here are examples that illustrate the use of technology by the pre-service teachers that indicate *Adapting* level for each component.

### Overarching Conception of Incorporating Technology into Teaching Subject.**

A pre-service teacher, Melinda, developed an interactive activity for 2\(^{nd}\) grade students on understanding of the place value and the properties of operations when adding and subtracting within 1000. To develop this activity Melinda used interactive Base Ten Blocks manipulative included in the Lesson Activity Toolkit in the SMART Notebook software. The activity created by Melinda included inquiry tasks for her students, as they applied their understanding of place value and properties of operations to add and subtract within 1000. By developing this interactive activity using SMART Notebook software, Melinda was able to connect topic learned in the course to practical applications of using instructional technology for her students’ learning of subject matter. The various options provided by the SMART Notebook software, such as
timed and untimed activities, image and sound support for text, etc. allowed Melinda to modify this activity to accommodate learners with different needs.

Knowledge of Students’ Learning Subject Matter with Technology. For her 1st grade students Sarah created a PowerPoint multimedia tutorial about the life cycle of a frog (see Figure 2.2). This tutorial provided an opportunity for the first grade students to learn how frogs change as they move through various life stages. Multimedia tutorial provided non-linear structure with easy navigation enabling students to use technology to learn science at their own pace. The interactive quiz developed as part of the tutorial served as self-assessment tool. By using multimedia tools and creating a PowerPoint multimedia tutorial, Sarah facilitated her students’ independent learning. She allowed students to explore the topic on their own. At the same time, pre-service teacher’s guidance was built-in into the tutorial.

Knowledge of Curriculum that Integrate Technology in Learning and Teaching. Jessenia developed a classroom blog for her 2nd grade science students to identify and compare physical structures of a variety of plant parts (see Figure 2.3). Students working in small groups researched about one of the parts of a plant and shared learned information with other students using various visual resources. In this case, Jessenia used instructional technology as a replacement for non-technology based tasks in a traditional curriculum, such as research using printed materials and communication of findings via posters and paper reports.
Knowledge of Instructional Strategies for Teaching and Learning with Technology. By learning interactive features of Excel, pre-service teachers were able to move from using technology as a drill and practice for their students to using it as an exploratory tool for acquiring new knowledge and/or skills. Amanda developed exploratory tool using advanced features of Excel, to support her 2nd grade students in solving word problems involving money. The Excel activity incorporated form controls (spinner arrows) allowing students to manipulate the number of dollars or cents to find the amount asked and provide various representation of the amount given. Students were able to observe effects of changes in multiple representations (graphical and numerical). The activity also included immediate feedback option that is especially important for students with special needs (see Figure 2.4).
Significant gains in TPACK scores indicate significant change in the teachers understanding and use of technology in the classroom upon completion of the course. The fact that pre-service teachers achieved level of \textit{Adapting} is consistent with existing research, Koh and Divaharan's (2011) study revealed that pre-service teachers need long-term exposure to courses designed around the TPACK framework in order to gain confidence in technology integration and moving up to the higher TPACK level. Even in-service teachers, despite of their experience and their knowledge of content and pedagogy, still only attained \textit{Accepting} level of the TPACK development after attending an ICT course and a year-long professional development program.
Another study showed that after a year-long professional development in-service teachers achieved at most *Adapting* level when integrating technology, as they tended to replace traditional instructional practices with technology (Lyublinskaya & Tournaki, 2011). The transition to higher, more advanced, levels of TPACK requires teachers to envision on their own how curriculum might be taught with the technology.

**Figure 2.** 4. Sample exploratory tool developed by one of the pre-service teachers.
This study has several limitations. First, there is lack of control group that is associated with single group design. Since the study was conducted in a required graduate level course, the control group would have created inequity in teacher preparation and thus was not possible. Another limitation of this study is the relatively small sample size.

**Significance of the study**

According to the results of this study, the TPACK framework-based course had a significant effect on pre-service elementary special education teachers’ TPACK. The pre-service teachers’ scores significantly improved in each TPACK component and overall. Integrating TPACK into special education teacher preparation courses could be valuable, as pre-service teachers learn how to use technology to support learning of all students. Allsopp et al (2009) argues that systematically integrating technology in a teacher preparation program can be very beneficial, especially to pre-service special education teachers struggling transferring “their abilities to use technology for developing products for learning and teaching purposes to teach students with disabilities” (p.349). Using a TPACK-based course in pre-service special education teachers’ education could help pre-service teachers to gain an understanding of how to integrate technology for learners with special needs. Moreover, as pre-service teachers experience added value of TPACK for integrating technology in their classrooms, their attitudes toward using technology could change for better.

The results of this study showed that basic domains of teacher knowledge within the TPACK Framework (TK, PK and CK) were not influenced by the TPACK-based course. However, pre-service teachers gained knowledge in all four components of the TPACK domain.
This could indicate the independence between basic domains of the TPACK Framework and TPACK construct. The study is significant as it is one of the first studies that suggests that TPACK could be an independent construct from TK, PK, and CK based on analysis of teaching artifacts rather than surveys. The further studies are needed to explore relationship between these four domains of the TPACK Framework.

**Implications**

When preparing new teachers to teach with technology, teacher educators need to be aware that teaching and learning is often about “imperfect information”, about “indirection, ambiguity, complexity, and multiplicity” (Bass, 1998, p.2). Not all technologies will work for every teacher or every student. Before using technology in their classrooms teachers must ask themselves a question: “how will this technology improve my teaching?” New technologies provide excellent opportunities for reaching the students with special needs and providing them with better access to learning.

Teacher educators are faced with the challenge of redesigning their programs with more emphasis on training new teachers how to use technology to enhance and differentiate student learning. There is a need for courses that integrate the teaching of all the domains of teacher knowledge: knowledge of a subject matter, pedagogy, and technology. Learning technical skills, disciplinary skills, or pedagogical skills alone is not sufficient – learning how to integrate technologies into teaching specific disciplines is equally important. More research is needed to assess the way teacher preparation programs are preparing new teachers to integrate technology in a transformative way, to enhance learning of all students.
References


CHAPTER 3. ANALYSIS OF RELATIONSHIP BETWEEN FIVE TPACK DOMAINS: TK, PK, CK MATH, CK SCIENCE, AND TPACK OF PRE-SERVICE SPECIAL EDUCATION TEACHERS.

A paper submitted to *Technology, Knowledge and Learning Journal*

**ABSTRACT**

This long-term single group study was conducted with pre-service special education elementary teachers taking a required graduate level course on integrating technology into mathematics and science instruction in a New York City public University. The purpose of this study was to explore whether Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge in mathematics and science (CKM and CKS) and Technological Pedagogical Content Knowledge (TPACK) are independent constructs in the TPACK framework and to develop instruments for assessment of each basic domain of the theoretical TPACK framework. Exploratory and confirmatory factor analyses of the developed instruments suggest that the TPACK construct is independent from TK, PK, CKM and CKS. Further analysis using multiple linear regression showed that TK, PK, and CK are not predictors of TPACK. These findings provide an opportunity for independent assessment of different types of teacher knowledge defined by the TPACK framework. This could help teacher preparation programs to evaluate effectiveness of courses that prepare teachers for integration of technology.
Introduction

New advances in educational technologies, increasing adoption rate of technologies in schools and strong emphasis on importance of technological tools in recently implemented new standards (Common Core State Standards for Mathematics, http://www.corestandards.org/Math/; Next Generation Science Standards, https://www.nextgenscience.org/) have placed new demands on classroom teachers to be knowledgeable and effective at teaching with technology and assessing the learning of students who use technology (Hutchison & Reinking, 2011). Research shows that many teacher education graduates feel unprepared to use technology to support student learning as they transition to teaching (Dawson, 2008; Ottenbreit-Leftwich, Glazewski, Newby, & Ertmer, 2010). This places higher demands on teacher preparation programs to ensure that novice teachers are capable of selecting, evaluating, and using appropriate technologies and resources to create experiences that advance student engagement and learning. (U.S. Department of Education, 2017). Teacher educators have increasingly looked to the theoretical framework of Technological Pedagogical Content Knowledge (TPACK), which is used to describe what teachers need to know to effectively integrate technology into their teaching practice (Mishra & Koehler, 2006). In the last decade, the TPACK framework has quickly become a widely referenced conceptual framework within teacher education, particularly as teacher education programs are redesigning their curriculum to prepare teachers to use technology effectively (Chai, Koh, & Tsai, 2010; Niess, 2011; Kaplon-Schilis, A., & Lyublinskaya, I., 2015).

The TPACK framework defines seven domains of teacher knowledge: TK (Technological Knowledge), PK (Pedagogical Knowledge), CK (Content Knowledge), PCK (Pedagogical Content Knowledge), TCK (Technological Content Knowledge), TPK (Technological Pedagogical Knowledge), and TPACK (Technological Pedagogical Content Knowledge).
Knowledge). TPACK domain as defined by Mishra and Koehler (2006) describes the nature of
knowledge that is required by teachers to teach with technology while addressing the complex
nature of teacher knowledge for specific subject areas (e.g. mathematics or science) within a
specific context. However, some researchers argue that it may be difficult to distinguish the
boundaries between different knowledge components of the TPACK framework (Graham, 2011).
Archambault and Barnett (2010) argue even further that TPACK domains are not separate from
each other and measuring these domains is “complicated and convoluted” (p. 1656), and
therefore it may be difficult to create instruments for measuring and assessing TPACK domain.

In order to address the effectiveness of teacher education programs, TPACK constructs
need to be precisely defined, and reliable instruments need to be created “for measuring and
assessing TPACK in a variety of context” (Shinas et al., 2013, p.340). According to Niess (2008)
providing the TPACK framework is not sufficient. Frameworks need to be tested in the real
world and the only way to do it is by developing appropriate instruments that are both
“consistent with the theory and measure what they set out to measure” (Koehler, Shin & Mishra,
2011, p.17). Since the development of the TPACK framework by Mishra and Koehler (2006),
researchers have been developing a variety of instruments to measure pre-service and in-service
teachers’ TPACK. Abbitt (2011) argues that the task of developing an efficient, reliable and
valid instrument is difficult, more so if you are trying to measure “how teacher’s knowledge
influences actual teaching practices” (p.288). The researchers question what would be the best
approach to develop pre-service teachers’ TPACK; what kind of knowledge base pre-service
teachers need to have in order to use appropriate technology tools to effectively facilitate all
students’ learning of specific content (Brantley-Dias & Ertmer, 2013). Some researchers debate
whether it is sufficient for pre-service teachers to be instructed focusing only on the construction
of a “unique body of TPACK knowledge” (Cherner & Smith, 2016). Others argue that teacher preparation programs should focus on training pre-service teachers separately in technology (TK), pedagogy (PK), and content (CK), and assume spontaneous integration of these domains into TPACK knowledge (Hughes, 2008). However, there is no sufficient research on how TK, PK, and CK affect the TPACK.

In order to analyze whether TK, PK and CK have an effect on TPACK, we need to determine whether theoretical domains defined by the TPACK framework could be measured independently. Therefore, the purpose of the study was to develop instruments that could measure each basic theoretical TPACK domain independently and analyze whether TK, PK, and CK are predictors of TPACK of preservice special education elementary school teachers. The following research question guided the study: Is there a relationship between basic domains of TPACK framework - TK, PK, and CK - and TPACK domain of preservice special education elementary school teachers?

**TPACK Framework**

TPACK was developed as a conceptual framework for inclusion of technological knowledge into Shulman's (1986) framework of "Pedagogical Content Knowledge (PCK)". Mishra and Koehler (2006) expanded Shulman’s framework by adding the knowledge of technology as a separate domain since technology, especially the digital technology, have changed (or can change) the nature of the classroom. The TPACK framework is identified with knowledge that teachers need for teaching with technology in their specific content areas and within specific context (Niess, 2008). The TPACK framework includes seven domains (see
Figure 3.1), that can be further classified as *basic domains*: TK – knowledge and proficiency with technology tools (Shinas et al., 2013), PK – knowledge of educational theories and instructional methodologies needed to develop appropriate instructions, and CK – knowledge of the subject matter; and *secondary domains*: TCK – knowledge of using technology tools to support specific content matter, PCK – knowledge needed to develop and deliver effective content-specific instruction, TPK – knowledge of how technology can support teaching and learning, and TPACK – knowledge that supports teacher’s ability to integrate content, pedagogy and technology in a unique context (subject matter, grade-level, teachers, school factors, demographics, culture, learning environment, etc.).

*Figure 3.1. The components of the TPACK framework ([http://tpack.org](http://tpack.org))*
Niess et al. (2009) developed a schema with detailed qualitative descriptors for the five levels of TPACK (i.e., recognizing, accepting, adapting, exploring, and advancing), and for each of the four components of TPACK (overarching conception, student understanding, curriculum, and instructional strategies) adapted from Grossman’s (1989) four components of PCK. (Figure 3.2). This qualitative schema was used to analyze the development of pre-service teachers’ TPACK in teaching mathematics with spreadsheets (Niess et al., 2010).

Figure 3. 2. Developmental model of TPACK through five progressive levels of teacher growth

TK, PK, CK and TPACK domains

“Teachers, who have TPACK, act with an intuitive understanding of the complex interplay between the three basic components of knowledge CK, PK and TK” (Baran, Chuang &
Recent studies focusing on the interaction between basic domains and secondary domains of TPACK framework produced mixed results. The question whether the basic domains of the TPACK framework affect the teachers’ TPACK domain has not been answered yet.

Most commonly used method to assess pre-service teachers’ TPACK includes self-reports, collected through surveys. According to Dong et al. (2015), the basic domains of TPACK framework, e.g. TK, PK, CK and the secondary domains, e.g. TPK, TCK, and PCK, “should act as epistemic resources to support the teacher’s development of TPACK” (p. 159). Some researchers argue that the basic domains of the TPACK framework are predictors of teachers’ TPACK, with PK having the largest impact on pre-service teachers’ TPACK (Chai et al., 2010). Other researchers suggest that although TK, PK, and CK are correlated with TPACK, TK is not a significant predictor of TPACK (Kartal & Afacan, 2017). Mishra and Koehler (2006) propose that the basic domains of TPACK framework might predict the TCK, PCK, TPK and TPACK but also indicate the need for further investigations. Koh et al. (2014) shows that although TK and PK positively affect TPACK, CK does not. Another study with pre-service teachers proposes that TK, PK, and CK have only indirect effects on TPACK, occurring through “the second layer of knowledge domains: TPK, TKC, and PCK.” (Chai et al., 2013, p. 41).

Pamuk et al. (2015) in his study also suggests that the second-level knowledge domains (TPK, TCK, PCK) have stronger impact on predicting pre-service teachers’ TPACK development than the basic domains (TK, PK and CK). The study conducted with pre-service science teachers focusing on pre-service teachers’ perception on TPACK suggests that all factors of TK, PK, CK, TCK, TPK, and PCK positively correlated with TPACK factors (Lin et al., 2013). Kaplon-Schilis and Lyublinskaya (2015) used external assessment to collect data for analyzing changes in the
TK, PK, CK and TPACK of pre-service special education elementary teachers. Researchers found that the basic domains of TPACK were not influenced by a technology-based pedagogical course for teaching mathematics and science, while TPACK significantly improved. This could have indicated the independence of TPACK domain from the basic domains of the TPACK framework. In order to further examine whether basic domains of TPACK affect teachers’ TPACK, we needed to investigate whether basic domains of the TPACK framework can be measured independently from TPACK domain. And if so, what instruments could be used to measure teachers’ TK, PK, CK, and TPACK.

Assessing TPACK

Assessing the complex construct of TPACK has been a challenge for the educational community. As a result, various types of data have been used in research to assess teachers’ TPACK. According to several reviews of the current TPACK studies (Tondeur et al., 2012; Mouza, 2016), the commonly used techniques for measuring pre-service teachers’ TPACK include analysis of teaching artifacts, classroom observations, interviews, self-assessment surveys, and questionnaires. The TPACK measurement instruments can be categorized into two types: self-assessment (most commonly used across TPACK studies) and external assessment (based on analysis of observed behavior and teaching artifacts). Studies focusing on issues related to measuring TPACK can be further categorized as qualitative (Archambault, 2016) and quantitative (Koh, Chai & Tsai, 2014).

Self-assessment (or self-reports) is mostly collected through surveys in which teachers report perceptions of their own TPACK. In most studies, researchers used surveys to measure
teachers’ knowledge in seven domains of TPACK framework (TK, PK, CK, TPK, TCK, PCK, and TPACK) using five to seven-point Likert scales (Chai et al., 2010; Archambault, 2016; Shinas et al., 2013). One of the commonly used surveys was developed and validated by Schmidt et al. (2009) to examine the changes in perceived TPACK of pre-service teachers’ during a semester of an introductory instructional technology course. Another commonly used survey developed and validated by Lee and Tsai (2010) allows assessment of teachers’ self-efficacy in terms of their TPACK. Although self-assessment instruments for measuring TPACK are easy to use, cost effective, and allow reaching large sample of participants, they represent the teachers’ perception of their TPACK that could be significantly different from the actual TPACK.

The advantage of external assessment is its higher objectivity compared to self-reports. External assessment of TPACK can be performed based on observed behavior and teaching artifacts. Most studies that analyzed teachers’ observed behavior utilized various qualitative techniques in order to measure TPACK based on meetings and interviews (Koehler et al., 2011), instructional observations (Mueller, 2010; Hofer & Grandgenett, 2012), and team conversations (Mishra et al., 2007). Fewer studies that focus on observed behaviors use quantitative analysis. Lyublinskaya and Tournaki (2012) developed scoring procedure for scripted narratives of instructional observations and teacher presentations at professional development meetings in order to measure teacher’s TPACK.

Another way of assessing teachers’ TPACK is by using teaching artifacts such as teachers’ electronic portfolios (Niess & Gillow-Wiles, 2010) and lesson plans (Harris, Grandgenett, & Hofer, 2010; Lyublinskaya & Tournaki, 2014). Harris, Grandgenett, and Hofer (2010) developed first quantitative measure of TPACK for lesson plans that assessed TPK, TCK, and TPACK. Lyublinskaya and Tournaki (2012) developed and validated TPACK levels rubric.
based on Niess’ schema for teacher growth for technology integration (Niess et al., 2009). This rubric was used in this study to assess pre-service teachers’ TPACK based on their lesson plans.

While all these studies suggest using various assessment instruments for measuring different domains of teacher knowledge identified in the TPACK framework, the question whether the basic domains of the TPACK framework affect the teachers’ TPACK is still not addressed. Moreover, it is still not clear whether TPACK domain can be measured independently from basic domains. Therefore, the purpose of this study was to analyze whether technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK) in mathematics and science, and the TPACK of pre-service special education elementary school teachers could be independently measured and then explore the relationship between these domains.

**The Study Context**

Data were collected from all pre-service special education elementary school teachers enrolled in a required graduate course on integrating technology in New York City public University over a period of four consecutive semesters. The objective of the course was to develop pre-service teachers’ TPACK for teaching mathematics and science to students with disabilities. The course met weekly for 15 two-hour sessions and one-hour lab session; all sections had the same instructor. Outside of the class meetings pre-service teachers were expected to spend 3-5 hours per week on computers to complete course assignments.

The course examined the use of traditional and emerging instructional technologies that are necessary to foster inquiry, enhance learning and reduce the achievement gap for students with learning disabilities. Pre-service teachers learned how to use various digital tools (e.g.
Microsoft office – advanced features of Word, PowerPoint, Excel; SMART Board and SMART Notebook software - interactive features and lesson activities toolkit; Geometer’s Sketchpad – dynamic geometry software for teaching and learning mathematics in grades 3–12; Data Collection – sensors/probes with various interfaces and platforms; calculators, Web 2.0 tools such as blogs, etc.) in elementary mathematics and science classroom. Within the course, pre-service teachers began understanding what role digital technology can play in teaching and learning mathematics and science in inclusion classrooms. Pre-service teachers used specific instructional technology tools to develop mathematics or science activities, and lesson plans that could be used by all students including those with learning disabilities. After learning how to differentiate instruction with technology, how to assess students’ learning using technology, how to use the technology to adapt instructions for learners with disabilities, how to engage and include all type of learners while using various instructional technologies, pre-service teachers developed and taught two lessons, one in mathematics and one in science, in variety of urban elementary classrooms.

**Methods**

**Participants**

During this study, a total of 116 pre-service teachers completed this required pedagogy course. Males comprised 7% of the group and females 93%. The majority of participants (67%) were between the ages of 23 and 26 years old, 7% between the ages of 18 and 22, 15% between the ages of 27 and 32, and 11% of the group were 33 years of age or older. The participants were considered pre-service teachers since they were enrolled in initial certification program for
special education; however, 39% of participants held a childhood teaching license, 15% an early childhood license, 3% a special education childhood license, 3% a special education adolescent license, and 40% did not have teaching license. The study sample was representative of the population that annually enrolls in this special education childhood education Master’s program.

On the tests used in this study the participants scored 60% on the test assessing PK, 70% on the test assessing TK, 80% on the test assessing CKM, and 73% on the test assessing CKS. These results are representative of the population involved in this study (Kaplon-Schilis & Lyublinskaya, 2015).

**Instruments**

**TKT - Technological Knowledge Test.** In order to develop basic technology literacy test aligned to the course curriculum, seven specific content areas were identified in accordance with the course's textbook (O'Bannon & Puckett, 2010). These areas included 1) hardware and software, 2) the Internet, 3) word processing, 4) digital images and diagrams, 5) databases, 6) spreadsheets, and 7) web authoring and multimedia (Table 3.1). Initially 51 multiple-choice questions assessing knowledge in these seven areas were selected from the test bank provided by the publisher of the textbook. In order to analyze construct validity, the test was sent to three experts in technology and technological literacy. Based on their comments, 5 items were eliminated due to ambiguity resulting in total of 46 questions requiring 30 minutes to complete. The experts also confirmed distribution of questions into seven identified content areas. The cumulative scores for each content area were defined as variables TKA - TKG and used for further analysis.
<table>
<thead>
<tr>
<th>Domain</th>
<th>Variable</th>
<th>#Questions</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>PK</td>
<td>PKA</td>
<td>6</td>
<td>Student Development and Learning</td>
</tr>
<tr>
<td></td>
<td>PKB</td>
<td>9</td>
<td>Instruction and Assessment</td>
</tr>
<tr>
<td></td>
<td>PKC</td>
<td>4</td>
<td>Professional Development</td>
</tr>
<tr>
<td>TK</td>
<td>TKA</td>
<td>4</td>
<td>Hardware and Software</td>
</tr>
<tr>
<td></td>
<td>TKB</td>
<td>6</td>
<td>The Internet</td>
</tr>
<tr>
<td></td>
<td>TKC</td>
<td>10</td>
<td>Word Processing</td>
</tr>
<tr>
<td></td>
<td>TKD</td>
<td>5</td>
<td>Digital Images, Diagrams</td>
</tr>
<tr>
<td></td>
<td>TKE</td>
<td>6</td>
<td>Databases</td>
</tr>
<tr>
<td></td>
<td>TKF</td>
<td>7</td>
<td>Spreadsheets</td>
</tr>
<tr>
<td></td>
<td>TKG</td>
<td>8</td>
<td>Web Authoring, Multimedia</td>
</tr>
<tr>
<td>CKS</td>
<td>CKSA</td>
<td>9</td>
<td>Physical Setting</td>
</tr>
<tr>
<td></td>
<td>CKSB</td>
<td>8</td>
<td>Life Science</td>
</tr>
<tr>
<td></td>
<td>CKSC</td>
<td>8</td>
<td>Earth and Space Science</td>
</tr>
<tr>
<td>CKM</td>
<td>CKMA</td>
<td>13</td>
<td>Number Properties, Operations</td>
</tr>
<tr>
<td></td>
<td>CKMB</td>
<td>7</td>
<td>Measurement</td>
</tr>
<tr>
<td></td>
<td>CKMC</td>
<td>4</td>
<td>Geometry</td>
</tr>
<tr>
<td></td>
<td>CKMD</td>
<td>4</td>
<td>Data Analysis, Statistics</td>
</tr>
<tr>
<td></td>
<td>CKME</td>
<td>6</td>
<td>Algebra</td>
</tr>
<tr>
<td>TPACK</td>
<td>Conception</td>
<td>n/a</td>
<td>Purpose for incorporating technology in subject matter</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>n/a</td>
<td>Students’ learning in subject matter with technology</td>
</tr>
<tr>
<td></td>
<td>Curriculum</td>
<td>n/a</td>
<td>Materials that integrate technology in learning &amp; teaching subject</td>
</tr>
<tr>
<td></td>
<td>Instruction</td>
<td>n/a</td>
<td>Instructional strategies for teaching &amp; learning subject with technology</td>
</tr>
</tbody>
</table>

**PKT - Pedagogical Knowledge Test.** The basic level of Pedagogical Knowledge was composed from the multiple-choice items of the New York State Teacher Certification Exam (NYSTCE) practice test for Elementary Assessment of Teaching Skills (http://www.nystce.nesinc.com). The validation process for the New York State Teacher Certification Examinations™ (NYSTCE®) tests followed professionally accepted procedures for
the validation of certification tests and was monitored by the New York State Education Department. New York Education Law, the Commissioner's Regulations concerning teacher certification, the New York State Learning Standards, and the input of thousands of practicing public school educators, college and university faculty were all considered in establishing the content validity of the tests. Validity evidence was gathered pertaining to the overall purpose of the tests, the content to be measured, and the specific test questions measuring test content. (http://www.nystce.nesinc.com/content/docs/NYSTCE_Validation_Reliability.pdf). Reliability information is accumulated with each NYSTCE test administration. Estimates of reliability for the NYSTCE tests required of all candidates for certification are typically in the range of 0.95 to 0.98.

The test included 19 multiple-choice questions that illustrate the objectives of the test - one question for each objective - in three distinct content areas: 1) student development and learning, 2) instruction and assessment, and 3) professional environment (Table 1). The test required 30 minutes to complete. The cumulative scores for each content area were defined as variables PKA - PKC and used for further analysis.

**CKMT – Content Knowledge in Mathematics Test.** The CKMT was comprised of released items from 2011 National Assessment of Educational Progress (NAEP) Grade 4 mathematics test using NAEP online test creation tool (http://nces.ed.gov/nationsreportcard/). The validity and reliability of the 2011 NAEP Grade 4 mathematics test has been verified based on nationally representative samples of 209,000 fourth-graders. The Pearson correlation, r, was used to assess scoring reliability. Correlations ranged from .85 to 1.00, indicating high scoring reliability. Inter-rater agreement was analyzed for each constructed-response item. Cohen's
Kappa for the constructed-response items ranged from .75 to .99. The percent of exact matches between the first and second scores ranged between 87% and 100% indicating high degree of agreement. (https://nces.ed.gov/nationsreportcard/tdw/analysis/).

The NAEP mathematics framework directs that questions to be based on the following five content areas: number properties and operations, measurement, geometry, data analysis, statistics, and probability, and algebra. The framework also specifies that each of the above content areas should occupy a certain proportion of the assessment (https://nces.ed.gov/nationsreportcard/mathematics/). Table 3.2 shows percentage distribution of items by content area in the CKMT in comparison with the NAEP test.

<table>
<thead>
<tr>
<th>Content Area</th>
<th>Number of items</th>
<th>Percent</th>
<th>NAEP percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number properties and operations (NO)</td>
<td>13</td>
<td>38</td>
<td>39</td>
</tr>
<tr>
<td>Measurement (M)</td>
<td>7</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>Geometry (G)</td>
<td>4</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Data analysis, statistics, and probability (DS)</td>
<td>4</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Algebra (A)</td>
<td>6</td>
<td>18</td>
<td>14</td>
</tr>
</tbody>
</table>

The CKMT included 34 multiple-choice, short and extended response items. The test required 30 minutes to complete. The cumulative scores for each content area were defined as variables CKMA - CKME (Table 3.1) and used for further analysis.

**CKST - Content Knowledge in Science Test.** The CKST was comprised of released items from 2009 National Assessment of Educational Progress (NAEP) Grade 4 science test using NAEP online test creation tool (http://nces.ed.gov/nationsreportcard/). The validity and reliability of the 2011 NAEP Grade 4 science test has been verified based on nationally
representative samples of 156,500 fourth-graders. The Pearson correlation, $r$, was used to assess scoring reliability. Correlations ranged from .78 to .98, indicating high scoring reliability. Interrater agreement was analyzed for each constructed-response item. Cohen's Kappa for the constructed-response items ranged from .90 to 1.00. The percent of exact matches between the first and second scores ranged between 83% and 100% indicating high degree of agreement (https://nces.ed.gov/nationsreportcard/tdw/analysis/).

The NAEP Science Framework describes the assessment content and how students' responses are evaluated. The assessment was designed to measure students' knowledge of three broad content areas reflecting the science content students are generally exposed to across the K-12 curriculum: 1) physical science, 2) life science, and 3) Earth and space sciences (https://nces.ed.gov/nationsreportcard/science). The framework recommends an approximately equal distribution of questions across the three content areas at grade four. In addition to science content, four science practices describe how students use their science knowledge by measuring what they are able to do with the science content: identifying science principles, using science principles, using scientific inquiry, and using technological design. Sixty percent of the 2009 assessment focused on conceptual understanding (i.e., identifying and using science principles), 30% focused on scientific inquiry, and 10% focused on using technological design.

The CKST included 25 multiple choice and constructed response questions that required 30 minutes to complete. The questions were almost equally divided between three content areas, 60% of questions focused on identifying and using science principles, 36% on scientific inquiry and 4% on using technological design. The cumulative scores for each content area were defined as variables CKSA - CKSC (Table 1) and used for further analysis.
**TPACK Levels Rubric.** The TPACK Levels rubric (Lyublinskaya & Tournaki, 2012) is designed to measure pre-service teachers' level of TPACK in four specific components of TPACK: *Conception, Students, Curriculum, and Instruction.* (Table 1). Two performance indicators have been developed for each level of each component consistent with the qualitative descriptors developed by Niess et al. (2009) and the principles for effective technology use (Goldenberg, 2000). The range of possible scores for each component is from 0 – 5, where the component score can be an integer (both performance indicators are met) or a half-integer (one out of two performance indicators are met). The score is assigned for each component independently. In order to achieve a particular level of TPACK, the pre-service or in-service teacher must meet both indicators of that level for each component. Thus, the lowest score across all four components determined the teacher’s total TPACK score. This score provided a conservative measure of the teacher’s level of TPACK development. The rubric was tested for reliability and validity. Content validity was ensured by employing two TPACK experts; both researchers who were involved in the initial development of the TPACK conceptual framework. They reviewed the rubric and provided written comments in response to three specific free-response questions about the rubric. The Pearson correlation, r, was used to assess scoring reliability. Correlations ranged from .61 to .68, indicating acceptable scoring reliability. Confirmatory Factor Analysis using varimax rotation with Kaiser Normalization was performed on two sets of 150 lesson plans collected from pre-service special education elementary school teachers. The procedure confirmed the four factors corresponding to four components of TPACK for each set of lesson plans (Lyublinskaya & Tournaki, 2014).
Data Analysis

Pohlmann (2004) suggests using factor analysis in evaluating the construct validity of new testing instruments. In order to analyze whether 22 variables defined in this study (see Table 3.1) form factors that load into five TPACK domains and therefore could be measured independently, we first tested assumptions of exploratory factor analysis (EFA).

Testing assumptions

Correlation analysis performed on 22 variables indicated that most items correlated with small to medium $r$ with at least one other item, suggesting reasonable factorability (Field, 2013). Bartlett’s test of sphericity was significant ($\chi^2 = 1119$, df =231, $p < .001$), confirming that R-matrix is not an identity matrix.

Only one correlation, between variables Conceptions and Students, was larger than the suggested cut off value of 0.9 that could indicate multicollinearity issues. However, an earlier study confirmed that these two variables were indeed independent (Lyublinskaya & Tournaki, 2014). Further, the determinant of the correlation matrix was $0.00002825 > 0.000001$ supporting assumption that R-matrix was not singular.

The variables in this study have been measured using different scales. However, according to Field (2013) using correlation matrix in factor analysis extraction ensures that the differences in measurement scales are accounted for.

With a sample of $N=116$, it was important to test whether the sample size was adequate for the factor analysis. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.73, which indicates that the sample size was adequate for the analysis (Hutcheson & Sofroniou, 1999). Further, the diagonals of the anti-image matrix were above 0.5 for all variables except for
PKC, and non-diagonal values of anti-image matrix were relatively small. Field (2013) suggests removing the variable with low KMO and see whether that will affect the adequacy of the sample. We verified that removing PKC did not affect testing assumptions of the factor analysis, and therefore PKC was kept for further analysis. Finally, the communalities ranged from .493 to .919 with the average of 0.683 well above suggested cut off value of 0.3 (Child, 2006).

According to Field (2013), as communalities become higher the importance of sample size decreases.

**Exploratory Factor Analysis**

A Principal Component Analysis (PCA) was conducted on 22 variables with Kaiser varimax rotation suppressing loadings less than 0.4. It led to extraction of seven factors with eigenvalues greater than one. Initial eigenvalues indicated that the first three extracted factors explained 20%, 16%, and 9% of the variance respectively. The fourth, fifth, sixth and seventh factors explained 6.8%, 6.3%, 5.3%, and 4.6% of the variance respectively with total of 68% of variance explained by the extracted factors. It is known that the Kaiser criterion works well when there are fewer than 30 variables (22 variables in our study) and if communalities are larger than .7 (Field, 2013). However, only seven out of 22 variables had communalities larger than 0.7 and therefore the Kaiser’s criterion most likely produced overestimated number of factors. Therefore, we also analyzed the scree plot (Figure 3.3).
As can be seen from the scree plot, the point of inflexion occurs at the 5th data point (factor), so according to Cattell (1966) we should retain four factors. The scree plot provides fairly reliable criterion for factor selection when sample size is 200 or more participants (Stevens, 2002), but in the case of this study (N = 116) it might provide an underestimated number of factors.

Based on Kaiser criterion and scree plot, the number of factors should be between four and seven. Since in this study we assessed five types of knowledge: TK, PK, CKM, CKS, and TPACK, confirmatory factor analysis (CFA) was conducted with five factors.

Figure 3.3. Scree plot for exploratory factor analysis
Confirmatory Factor Analysis

The purpose of the CFA was to verify the factor structure of the observed variables and to confirm that observed variables load to theoretical constructs defined by the TPACK framework.

A CFA with five factors was conducted on 22 variables using Kaiser varimax rotation suppressing loadings less than 0.4 (see Table 3.3).

Table 3. 3 Rotated Components Matrix for Initial Confirmatory Factor Analysis with 22 Variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
<th>Factor 4</th>
<th>Factor 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>PKA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.661</td>
</tr>
<tr>
<td>PKB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.539</td>
</tr>
<tr>
<td>PKC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.685</td>
</tr>
<tr>
<td>TKA</td>
<td></td>
<td></td>
<td></td>
<td>.609</td>
<td></td>
</tr>
<tr>
<td>TKB</td>
<td></td>
<td></td>
<td>.565</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TKC</td>
<td></td>
<td></td>
<td></td>
<td>.478</td>
<td></td>
</tr>
<tr>
<td>TKD</td>
<td></td>
<td></td>
<td></td>
<td>.439</td>
<td></td>
</tr>
<tr>
<td>TKE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TKF</td>
<td></td>
<td></td>
<td></td>
<td>.702</td>
<td></td>
</tr>
<tr>
<td>TKG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.544</td>
</tr>
<tr>
<td>CKMA</td>
<td>.526</td>
<td></td>
<td>.485</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CKMB</td>
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<td>.770</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CKMC</td>
<td></td>
<td>.729</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CKMD</td>
<td></td>
<td></td>
<td>.744</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CKME</td>
<td></td>
<td></td>
<td></td>
<td>.699</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>CKSA</td>
<td>.765</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CKSB</td>
<td>.829</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CKSC</td>
<td>.798</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conception</td>
<td>.939</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students</td>
<td>.956</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curriculum</td>
<td>.928</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instruction</td>
<td>.934</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eigenvalues</td>
<td></td>
<td>4.42</td>
<td>3.53</td>
<td>2.00</td>
<td>1.49</td>
</tr>
<tr>
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<td>20.11</td>
<td>16.05</td>
<td>9.09</td>
<td>6.78</td>
</tr>
</tbody>
</table>

As can be seen from the Table 3.3, except for two variables (CKMA with cross-loadings and TKE that did not load to any of the factors) all variables loaded into five factors that represent five domains of TPACK. Therefore, from 22 original variables, we omitted these two variables and repeated the CFA procedure with 20 variables (Table 3.4). The CFA yielded five independent factors with loadings ranging from 0.428 to 0.957 corresponding to five domains: TPACK, TK, PK, CKM and CKS. According to George and Mallery (2001) this range of loadings is considered to be acceptable to excellent. In addition, reproduced correlation matrix showed that 37% of residuals were greater than 0.05, which supported the good fit of the model with five factors (Field, 2013).

Internal consistency and reliability of each individual instrument was tested using Cronbach’s $\alpha$ analysis and results of the analysis are shown in Table 3.4. TPACK levels rubric, CKMT and CKST had high reliabilities with $\alpha=.96$, $\alpha=.81$, and $\alpha=.80$ respectively. However, TKT and PKT had relatively low reliability with $\alpha=.62$ and $\alpha=.40$, respectively (Table 3.4).
Table 3. 4 *Rotated Components Matrix for Final Confirmatory Factor Analysis with 20 Variables*

<table>
<thead>
<tr>
<th></th>
<th>Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td>PKA</td>
<td>.671</td>
</tr>
<tr>
<td>PKB</td>
<td>.565</td>
</tr>
<tr>
<td>PKC</td>
<td>.668</td>
</tr>
<tr>
<td>TKA</td>
<td>.630</td>
</tr>
<tr>
<td>TKB</td>
<td>.570</td>
</tr>
<tr>
<td>TKC</td>
<td>.466</td>
</tr>
<tr>
<td>TKD</td>
<td>.428</td>
</tr>
<tr>
<td>TKF</td>
<td>.710</td>
</tr>
<tr>
<td>TKG</td>
<td>.555</td>
</tr>
<tr>
<td>CKMB</td>
<td>.754</td>
</tr>
<tr>
<td>CKMC</td>
<td>.754</td>
</tr>
<tr>
<td>CKMD</td>
<td>.741</td>
</tr>
<tr>
<td>CKME</td>
<td>.708</td>
</tr>
<tr>
<td>CKSA</td>
<td>.785</td>
</tr>
<tr>
<td>CKSB</td>
<td>.831</td>
</tr>
<tr>
<td>CKSC</td>
<td>.803</td>
</tr>
</tbody>
</table>
Multiple linear regression

In order to explore whether TK, PK, CKM and CKS are predictors for TPACK we used multiple linear regression analysis. According to Green (1991) the sample size of 116 > 109 is adequate for testing individual predictors using regression analysis. Analysis of bivariate correlations between variables indicated that there were no multicollinearity threats - the highest correlation was between CKM and CKS (r = .395, p < 0.001). At the same time, there were no significant correlations observed between TPACK and the four variables to be analyzed.

The Durbin-Watson statistic value was 2.006, so the assumption of independent errors has been met. The data do not have collinearity issues as confirmed by the fact that all individual VIF values were a little over 1 with average VIF value 1.15 with tolerance .87. In addition, each variable had most of variance loading onto a different dimension (PK had 81% of variance loaded onto dimension 2, TK - 74% onto dimension 5, CKM - 66% onto dimension 3, and CKS - 94% onto dimension 4) which supports non-collinearity assumption. There were 5
cases with standardized residuals less than -2 or larger than 2 which is 4% of the sample and within allowed 5%.

The model produced R squared value of 0.005 - only 0.5% of variance in TPACK is accounted for by TK, PK, CKM and CKS. ANOVA analysis confirmed that the model is not a significant fit ($F(4,111) = .150, p = .962$). Analysis of the coefficients of the model further supported conclusion that TK, PK, CKM and CKS are not predictors for TPACK (Table 3.5).

Table 3.5 *Multiple Linear Regression Model.*

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>SE</th>
<th>$\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>2.551</td>
<td>.632</td>
<td></td>
</tr>
<tr>
<td>PK raw</td>
<td>.000</td>
<td>.026</td>
<td>-.002</td>
</tr>
<tr>
<td>TK raw</td>
<td>.002</td>
<td>.019</td>
<td>.010</td>
</tr>
<tr>
<td>CKM raw</td>
<td>.006</td>
<td>.016</td>
<td>.040</td>
</tr>
<tr>
<td>CKS raw</td>
<td>.006</td>
<td>.016</td>
<td>.044</td>
</tr>
</tbody>
</table>

**Discussion**

**Instruments and domains**

The goal of this study was to analyze the relationship between the basic domains of TPACK framework (TK, PK, and CK) and TPACK of pre-service elementary special education teachers, and therefore it required instruments that could measure these domains independently. Examination of the existing instruments revealed that while there were plenty of reliable self-reported surveys used to evaluate the basic domains of TPACK framework, there were no reliable external assessment tools. Therefore, the study first focused on development of such instruments for TK, PK, and CK in mathematics and science.
The Technology Knowledge Test (TKT) needed to assess pre-service teachers’ “basic technological literacy” without connecting that to the pedagogical or content knowledge. The questions were selected to address specific areas for technological literacy indicated in the course’s textbook and confirmed by experts in technology and technological literacy (Table 3.1). The variables were defined based on these content areas; however, confirmatory factor analysis showed that one of the variables, measuring knowledge of databases, did not load to any of the factors and therefore was eliminated. One of the possible explanations could be the fact that this instrument was tested with population of pre-service elementary school teachers who did not have any experiences with databases. Even though construct validity of variables were confirmed by technology experts, the TKT scale resulted with relatively weak internal consistency (Cronbach $\alpha$ value of .62) and needs further validation with larger samples.

In developing instruments to measure pre-service teachers’ PK and CK (in mathematics and science), questions were selected from released items with confirmed validity and reliability. The questions for assessing CKM and CKS came from released items of NAEP and the values of Cronbach’s $\alpha$ showed high reliabilities for CKMT and CKST, confirming good internal consistency of these two tests. However, PKT that was developed from practice test for NYSTCE had much lower than expected reliability ($\alpha=0.40$), even though official documentation reports estimates of reliability for the NYSTCE tests in the range of 0.95 to 0.98. According to Tavakol and Dennick (2011), Cronbach’s $\alpha$ is sensitive to the number of items in a test. A smaller number of items very often results in a smaller $\alpha$. The number of items on the PKT was 19, about four times less than number of items on actual certification exam (80 multiple-choice questions). Using Spearman-Brown prophecy formula (Nunnally & Bernstein, 1994) reliability of .95 on a full test should have led to at least .8 for the value of $\alpha$ on PKT.
Nevertheless, three variables that defined PK loaded into one factor suggesting that this factor assessed pedagogical knowledge.

Making decisions on the number of factors should be based on theory and empirical research (Chai et al., 2010). The results EFA suggested that the number of factors could be between 4 and 7. The theory suggest that TK, PK, CKM, CKS, and TPACK should be considered as different constructs (Mishra & Koehler, 2006), and therefore five factors were used for the CFA. The loadings ranged from 0.428 to 0.957. According to George and Mallery (2001) this range is considered to be acceptable to excellent.

As a result of CFA another variable, CKMA, was removed due to loading onto two factors. The decision to remove this variable is supported by Schonrock-Adema et al. (2009) stating that a variable that loads on more than one factor should be removed if the cross-loading is greater than 0.40. Analysis of the correlations matrix shows that CKMA had statistically significant correlations ranging from .384 to .467 ($p < .001$) with all three variables for CKS and that led to cross-loading. CKMA measured knowledge in the content area of number properties and operations. Further analysis is needed to interpret why this variable loaded almost equally onto mathematics and science factors.

Based on results of the final CFA, after two variables were removed, it can be concluded that the four basic domains of TPACK and the TPACK domain itself could be independently measured using this study’s instruments. Further analysis using multiple linear regression showed that there were no significant correlations observed between TPACK and TK, PK and CK (in mathematics and science). The testing of the model also confirmed that TK, PK, and CK (in mathematics and science) were not predictors for TPACK.
The practical application of this study is the validation of the instruments to measure the TK, PK, and CK (in mathematics and science) of preservice special education elementary school teachers. The results of factor analysis are good indications that the developed instrument is a reliable measure of TK, PK, CK (in math and science) of graduate level pre-service elementary school teachers. The results from the multiple regression also suggest that the basic domains of TPACK: TK, PK and CK are not predictors for TPACK and therefore can be developed and measured independently. However, the independent development of pre-service teachers’ TK, PK, and CK does not guarantee the development of their TPACK. Based on the results, by increasing pre-service teachers TK, PK, and CK schools of education do not necessarily increase pre-service teachers TPACK. Therefore, teacher preparation programs need to focus on developing teachers’ TPACK in addition to developing teacher’s basic knowledge, such as TK, PK and CK in order to help new teachers to gain the knowledge and skills to effectively integrate technology in their classrooms.

**Significance of the study**

The rapid transition to digital learning in America’s schools, challenges teacher preparation programs to prepare pre-service teachers on how to use instructional technology. At the same time, many pre-service teachers do not feel adequately prepared to use technology effectively in their classroom after they graduate (Gray et al., 2010). The TPACK framework may provide the guidance in redesigning teacher preparation to assure they integrate technology (Bos, 2011; Özgün-Koca, Meagher, & Edwards, 2010; Kaplon-Schilis & Lyublinskaya, 2015),
but there is a need for instruments that would allow to measure the effectiveness of these programs by assessing pre-service teachers’ knowledge in using technology in the classroom.

This study developed instruments that could independently measure each basic domain of TPACK. To the best of our knowledge this is the first study that developed and validated the instrument for external assessment of TK, PK, CK (in mathematics and science), and TPACK of preservice special education elementary school teachers. Furthermore, to the best of our knowledge, this study is the first one that provides initial evidence that TPACK is an independent construct from TK, PK, and CK in the context of integrating technology into teaching mathematics and science by special education pre-service elementary school teachers. Study results also suggest that four basic domains of TPACK are not predictors for TPACK.

The limitation of the study is the relatively small sample size (N=116), and the very specific population group, since the instruments were designed with a specific purpose in mind: examining basic knowledge of pre-service elementary school special education teachers’ and their development of TPACK. These findings need to be further confirmed with larger sample and different populations. The use of the instrument in different settings and context needs to be further investigated (e.g. elementary school general education teachers). Future study will also focus on determining the factors that contribute to pre-service teachers’ TPACK development, including exploring relationship between all seven domains of the TPACK framework.
References


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Mouza, C. (2016). Developing and assessing TPACK among pre-service teachers. In M. Herring, M. Koehler, & P. Mishra (Eds.), *Handbook of Technological Pedagogical Content Knowledge (TPACK) for Educators*, 169 - 188.


ABSTRACT

This case study analyzed the Technological Pedagogical Content Knowledge (TPACK) development and a learning trajectory of a single pre-service special education elementary school teacher during a TPACK-based graduate pedagogy course and TPACK transfer from this course to the teaching during the induction year. The case study was guided by the following research questions: 1) What instructional strategies and experiences in the graduate pedagogy course supported TPACK development of this pre-service teacher? 2) What are the internal and external factors affecting TPACK transfer for this teacher? The study showed that the TPACK level of the participant increased to the Exploring level of TPACK throughout the graduate course, but regressed to Adapting level during first year of teaching showing partial transfer of TPACK. The study described course experiences and instructional strategies that supported the pre-service teacher’s TPACK development in the graduate course and identified some external and internal factors that could have affected the transfer of TPACK from college classroom to teaching.
Introduction

The rapid transition to digital learning in America’s schools has made it challenging for teacher preparation programs to stay in the forefront of this change. According to Ottenbreit-Leftwich et al. (2012) many pre-service graduates feel unprepared to use technology effectively in their classroom practice on their first day of in-service teaching. Many in-service teachers do not find specific technology skills they have learned in their pre-service teacher education programs meaningful or relevant to their teaching practices. The Technological Pedagogical Content Knowledge (TPACK) framework, which is used to describe what teachers need to know to effectively integrate technology into their teaching practice (Mishra & Koehler, 2006), has been developed in response to these challenges. In the last decade, the TPACK framework has quickly become a widely referenced conceptual framework within teacher education, particularly as teacher education programs are redesigning their curriculum to provide a systematic and meaningful way of preparing teachers for technology integration to address the needs of all students (Chai, Koh & Tsai, 2010; Lyublinskaya, 2015).

The purpose of this case study was to analyze the TPACK development and a learning trajectory of a single pre-service special education elementary school teacher during a TPACK-based graduate pedagogy course and the TPACK transfer from this course to the teaching during the induction year. The case study was guided by the following research questions: 1) What instructional strategies and experiences in the graduate pedagogy course supported TPACK development of this pre-service teacher? 2) What are the internal and external factors affecting TPACK transfer for this teacher?
Background

This section presents literature review that introduces the TPACK framework, provides an overview of current research on TPACK with the focus on pre-service and in-service special education, and describes current studies on the teacher development, the transfer of knowledge from pre-service to in-service experience, as well as learning trajectories for teachers.

TPACK Framework

The TPACK framework as described by Mishra and Koehler (2006) was built upon Shulman’s (1986) idea of PCK (Pedagogical Content Knowledge) framework by adding the knowledge of technology as a separate domain, since technology, especially digital technology, have changed (or can change) the nature of the classroom. The TPACK framework describes the knowledge that teachers need for effective integration of technology in their specific content areas and grade levels (Niess, 2008). Seven knowledge domains described by the TPACK framework include: Technological Knowledge (TK) as knowledge and proficiency with technology tools (Shinas et al., 2013), Content Knowledge (CK) as knowledge of the subject matter, Pedagogical Knowledge (PK) as knowledge of educational theories and instructional methodologies needed to develop appropriate instructions, Technological Content Knowledge (TCK) as knowledge of using technology tools to support specific content matter, Pedagogical Content Knowledge (PCK) as knowledge needed to develop and deliver effective content-specific instruction, Technological Pedagogical Knowledge (TPK) as knowledge of how technology can support teaching and learning, and TPACK as knowledge that supports a
teacher’s ability to integrate content, pedagogy and technology in a specific context (subject matter, grade-level, teachers, school factors, demographics, culture, learning environment, etc.).

**Progressive Levels of TPACK**

Niess, van Zee and Gillow-Wiles (2010) adapted Rogers’ (1995) five-stage sequential model of the innovation-decision process for TPACK to describe five progressive levels of TPACK: recognizing, accepting, adapting, exploring, and advancing. According to this developmental model of TPACK, when learning to integrate a particular technology a teacher progresses through five levels: Level 1 (*Recognizing*) where teachers do not integrate technology in teaching and learning, even though they are able to use technology and recognize the place of technology within specific content. Level 2 (*Accepting*) where teachers form a positive or negative attitude towards teaching and learning with specific technology. Level 3 (*Adapting*) where teachers make decisions to adopt or reject technology for teaching and learning. Level 4 (*Exploring*) where teachers integrate an appropriate technology for teaching and learning of the specific content. Level 5 (*Advancing*) where teachers confirm and evaluate results of integrating an appropriate technology for teaching and learning of the specific content.

Using TPACK framework-based courses in teacher preparation programs may help pre-service teachers acquire the knowledge and skills necessary to prepare them for effective technology integration into the classroom (Tondeur et al., 2017). Current studies suggest that the TPACK framework-based courses allow pre-service teachers to increase their TPACK (Akman & Guven, 2015; Durdu & Dag, 2017). Although, many researchers agree on the need to re-evaluate and redesign teacher education courses to prepare pre-service teachers to effectively
incorporate technology (Goktas, Yildirim, & Yildirim, 2009), there is no consensus on what the most effective approach to TPACK development is (Hofer & Grandgenett, 2012).

### Learning Trajectories

There are many studies suggesting various learning trajectories in the educational course that may help supporting the development of pre-service teachers’ TPACK. Cavin (2008) suggested that pre-service teachers increase their TPACK by developing technology-enhanced lessons through a recursive process of micro-teaching, reflection, and revision. Hu and Fyfe (2010) described a positive impact on pre-service teachers’ self-rated TPACK in a course that was organized around a series of problem-centered design tasks. Jang and Chen (2010) suggested that a transformative model of integrating technology with peer/tutor coaching can help pre-service teachers to develop and further enhance their TPACK. Özgün-Koca, Meagher, and Edwards (2010) showed that TPACK development is related to pre-service teachers’ shift in viewing technology: initially a tool for reinforcement becomes a tool for developing student understanding. The authors also suggested that “experiencing success in the classroom” (p.19) is another important element in continuing the development of TPACK. Another study focusing on the pedagogy course designed around the TPACK framework demonstrated that the TPACK level of the graduate pre-service special education teachers significantly increased upon completion of the course (Kaplon-Schilis & Lyublinskaya, 2015). The biggest limitations of these studies has been that the development and gains in pre-service teachers’ TPACK were mostly studied using pre-posttest design within one course.
Knowledge Transfer

The transfer of learning indicates capacity of applying learned knowledge and skills in a different context (Perkins & Salomon, 1992). In teacher education the transfer of knowledge indicates that the pre-service teacher is able to integrate, apply, and use knowledge and skills gained in the college classroom to teaching in his/her own classroom. In order to increase pre-service teachers’ knowledge transfer, researchers suggest to allow sufficient instructional time for development of concepts and procedures (Alexander, 2006), for cooperative and collaborative activities, for peer discussions (Veenman et al., 2002), and for authentic tasks and assessment (Darling-Hammond & Bransford, 2007). De Jong et al. (2010) suggest that Group-Based Learning in pedagogy courses promotes effective transfer of knowledge. Dickenson (2017) recommends that integrating Universal Design for Learning principles and guidelines into course content would promote transfer of pre-service special education teachers’ knowledge from theory to practice.

As pre-service teachers develop TPACK in teacher education programs, they are expected to transfer their knowledge and skills into their future classrooms (Brush et al., 2003). Understanding how teachers transfer their knowledge from the teacher preparation courses to their teaching practice is crucial; however, there is limited research on TPACK transfer of pre-service teachers. The recent qualitative studies show that teachers may have initial ability to transfer what they have learned in their pedagogy course when specific instructional strategies are used in a pedagogy course to increase teachers’ TPACK level such as live dual modeling (Lu & Lei, 2012) and game-based learning (Jupit et al., 2012). Lyublinskaya and Tournaki’s earlier study based on the graduate pedagogy course considered in this current study showed that only 64% of pre-service teachers fully transferred their TPACK from the TPACK-based pedagogy
Teacher Development

Research suggests that teachers go through developmental stages once they begin teaching. Most theories focus on a chronological framework unrelated to background of the teacher or teaching context (Watzke, 2003). However, other factors influence (determine) the development of novice teachers in their induction year.

Internal factors such as a teachers’ vision such as the teachers’ beliefs, passions, attitudes towards teaching and images of themselves, play an important role in the teachers’ development (Vaughn & Parsons, 2012). When new teachers are passionate about teaching, and believe in their readiness for the task, they are more likely to “survive” the first year without the feeling of emotional inadequacy. Teachers’ metacognition, their awareness of their own thinking, helps new teachers to regulate their actions. According to Duffy et al. (2009) new teachers develop an awareness about their work, while participating in dialogue about teaching, through self-reflection and practice. Another study shows that the graduate courses, especially instructor’s feedback and instructional modelling, increase new teachers’ responsiveness to their own students (Parsons et al., 2017).

External factors influencing teachers’ development have their base in social constructivism (Vygotsky, 1978). Teachers are more likely to develop usable knowledge if their learning is situated in practice. Factors including work communities, work conditions, school district, class sizes, grade level, high stakes testing, limited resources, and school support influence novice teacher’s classroom practice (Ingersoll, 2012). Feiman-Nemser (2003)
Suggested mentoring during the novice year as a strategy that can provide new teachers with a safe environment to develop and prepare for all the contextual factors.

Research suggests that teachers’ intense phases of development during their first years influences their use of technology in the classroom (Parsons et al., 2017). Ertmer et al. (2012) argue that new teachers need to be provided with attention and support (modeling technology integration), starting in their pre-service training and continuing during their first years of teaching, in order for new teachers to use technology for development of higher-order thinking in a student-centered environment. Inan and Lowther (2010) also suggest that a teachers’ readiness has the highest total effect on their future technology integration.

**Methods**

The goal of the study was to analyze the instructional strategies and experiences in the graduate pedagogy course that supports TPACK development of pre-service teachers and to explore the internal and external factors affecting TPACK transfer. This study followed a longitudinal mixed methods single subject case-study research design. Collected data included three technology-infused lesson plans developed at the beginning and at the end of the graduate pedagogy course, and at the end of the first year of teaching, videos of teaching each of the three lessons, and four technology-based activities developed throughout the pedagogy course. These artifacts were scored using the TPACK Levels Rubric (Lyublinskaya & Tournaki, 2012). In addition, the study analyzed self-reflective papers on the participants’ teaching written at the end of the graduate pedagogy course and transcript of the phone interview conducted at the beginning of the second year of teaching.
**Context**

This case study was part of a larger research project conducted in New York City public university over eight consecutive semesters in a graduate pedagogy course on integrating technology into mathematics and science instruction for students with learning disabilities required for the Master in Special Education program. The course examined the use of traditional and emerging instructional technologies that were necessary to foster inquiry, enhance learning and reduce the achievement gap for students with learning disabilities. The course content and the activities were developed and organized around the TPACK framework and the course was divided into three major sections: 1) introduction to the TPACK framework and the theoretical aspects of technology integration; 2) focus on different roles of technology in teaching mathematics and science in inclusion and self-contained classrooms; and 3) evaluation and reflection on teachers’ own professional practice (Lyublinskaya, 2015). The course met weekly for 15 two-hour sessions and one one-hour lab session. (see Table 4.1 for course outline).

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Experiences</th>
<th>Collected assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction. TPACK framework overview.</td>
<td>Assessment of teachers’ knowledge. Special education walk activity and discussion.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Models and strategies for technology-infused lessons.</td>
<td>Whole class discussion of principles of effective use of technology. Small group video analysis of technology-infused lessons.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Using research and communication tools to enhance learning. Role of Internet and word processing.</td>
<td>Lab activity: What Are the Chances of Severe Weather? Internet-based research and sharing results via blog. Workshop - create your own blog.</td>
<td></td>
</tr>
<tr>
<td>Lesson Plan 1</td>
<td>Workshop on basic and advanced features of Smart Notebook software. Developing interactive activities with Lesson Toolkit and Activity Builder.</td>
<td>Blog</td>
<td></td>
</tr>
<tr>
<td>Lesson Plan 2</td>
<td>Video analysis of lessons from online teaching resources (Annenberg Learner).</td>
<td>Self-assessment paper</td>
<td></td>
</tr>
</tbody>
</table>

**Participant**

For the purpose of this case study of a single participant, the participant is called Amanda. Amanda was one of the eight teachers who agreed to participate in the case study conducted during their first year of teaching. The participation involved providing a lesson plan...
and video of teaching a mathematics or a science lesson with technology and participating in a phone interview. Amanda is a Caucasian female who was 27-years old at the time of the interview. As an undergraduate, she was a remedial mathematics student, taking 12 semesters (including one summer) to complete her undergraduate program in early childhood education. She earned a Master of Special Education degree in childhood education in seven semesters (including two summers). Amanda was enrolled in the TPACK-based pedagogy course considered in this study during her fourth semester of graduate school. She started teaching exactly one year after she took the course, in a first grade integrated collaborative teaching classroom in a New York City Title I elementary school.

**TPACK Levels Rubric**

The TPACK Levels Rubric was used to assess student artifacts (Lyublinskaya & Tournaki, 2012). The structure of the rubric is based on the TPACK framework for assessing the development of a teachers’ classroom technology integration across five progressive levels [recognizing (1), accepting (2), adapting (3), exploring (4), to advancing (5)] in each of the four components of TPACK (conception, students, curriculum, and instruction) adapted by Niess (2005) from Grossman’s four components of PCK (1989).

The TPACK Levels rubric is organized as a matrix, with each cell representing specific TPACK level for one of the four components of TPACK. Two performance indicators were developed for each level of each component consistent with the qualitative descriptors developed by Niess et al. (2010) and the principles for effective technology use (Goldenberg, 2000). The indicators assess the level of teacher and student involvement with technology. The range of possible scores for each component is from 0 – 5, where the component score could be an integer.
(both performance indicators are met) or a half-integer (one out of two performance indicators are met). The score is assigned for each component independently. In order to achieve a particular level of TPACK, the artifact must meet both indicators of that level for each component. Thus, the lowest score across all four components determines the teacher’s total TPACK score. This score provided a conservative measure of the teacher’s level of TPACK development. The rubric was tested for reliability and validity (Lyublinskaya & Tournaki, 2012).

Results

TPACK Development Analysis

Amanda’s undergraduate program did not involve experiences with technology for teaching, therefore, the researchers assumed that initially Amanda did not have the TPACK for teaching mathematics or science (level 0). The study first examined artifacts that Amanda developed in the graduate course in order to analyze her learning trajectory and TPACK development in relation to her experiences in the course. The first three sessions of the course focused on the theoretical aspects of using technology for teaching mathematics and science. During these sessions, models and strategies for technology-infused lessons were discussed and videos of exemplary teaching of mathematics and science were analyzed against the principles of effective use of technology (Goldenberg, 2000). During the same time, pre-service teachers worked on their first technology-infused lesson plan that they submitted by the fifth week.

Amanda developed the lesson plan for a second grade science topic the life cycle of a plant. In this lesson she planned to show a relevant BrainPop Jr. video to her whole class to introduce a new topic; however, Amanda did not plan to pause the video to question her students,
or to provide them with opportunities to reflect on the material presented in the video. The follow up student activity did not include inquiry tasks or explorations. The students were just asked to search for pictures of their “favorite” stage of life cycle and type in a sentence explaining why they liked that stage. The technology did not support student learning of the topic and the choice of technology for student activity was not appropriate for the topic. In this lesson technology was used primarily as a motivational tool. At the same time, technology use by students involved some independent tasks, in addition to drill and assessment. Therefore, the lesson plan met one of the criteria at the Adapting level with the score of 2.5 for Curriculum component and the criteria of the Accepting level for all other components with the score of 2.0.

The choices that Amanda made for her instruction and student activity in the lesson plan reflected her initial understanding of the material discussed in the course in the first three weeks. She included technology-based activity for her students, as she learned in the course that effective use of technology should involve students exploring topics with the technology. She also chose a more engaging form of delivering new information to the students by using a video with an embedded quiz and interactive vocabulary rather than a traditional PowerPoint presentation with follow up oral questions.

The next nine sessions of the course (weeks 4 -12) focused on specific roles of instructional technology in teaching and learning mathematics and science and adaptations of technology-based instruction for students with learning disabilities. Each class session included either a technology-based activity to allow pre-service to teachers to experience the activity from the students’ perspectives, or exercise in the development of technology-infused activities for their future classrooms. The pre-service teachers had an opportunity to reflect on their
experiences with technology, analyze the activities against the principles for effective use of technology, and discuss adaptations for the students with learning disabilities.

During the fourth week, the course instruction focused on the role of the Internet and word processing in research and communication in the mathematics and science elementary classrooms. The pre-service teachers completed a fourth-grade activity to research specific severe weather conditions and to share their findings via the class blog. Upon reflection on the experience, the pre-service teachers had to create their own classroom blog that was completed by week six. Amanda created a blog for the first grade science topic about seasons, asking her students to observe and describe weather conditions during different seasons using a pre-selected website. Per assignment requirements, she included two posts - one with instructions for her students and one with an example of expected work (Figure 4.1).

\[ \text{a. Instructions for students} \]

**Instructions**

Spring is upon us, and with that comes many changes to our ecosystem. Each change of the season brings different weather, temperatures, and plant life. By exploring this blog, each student will learn about and be able to describe weather conditions that occur during each season.

For this assignment:

1. Read *Live Science - The Four Seasons* and explore the gallery located under each season.
2. Pick one season you would like to describe in your blog post.
3. Provide facts about the season and the weather it is accompanied by.
4. Post one external link that could provide us with more information on your topic, and why?

\[ \text{b. Sample student post} \]

**Student Post**

Springtime means warmer weather and longer daylight hours. Seeds begin to grow so do vegetables. Flowers begin to bloom and leaves begin to bud. The weather is usually sunny, but it also rains a lot. Animals that hibernated throughout the winter wake up, and animals that traveled south return home with their babies.

In her instructions (Figure 4.1a) Amanda provided a hyperlink for her students to a website that was not age appropriate and just mirrored the printed text. Her example post was
about the spring season (Figure 4.1b) but she did not make sure that all three seasons were assigned to the students in order to meet the learning objectives. Amanda did not fully understand the purpose of the blog as a tool to share information where students can learn from each other. Rather, students were to complete their entries but were not asked to read each other’s blogs. Her instructions did not provide students with any guidance on how to conduct the research or how to insert images and hyperlinks into a blog post. Therefore, the use of technology in this activity was considered as purely motivational. This activity was scored at Accepting level with score of 2.0 for all components.

During sessions five and six, the pre-service teachers learned about the purpose of various visual tools for supporting student learning in mathematics and science, as well as for differentiation of instruction and assessment. Since most schools in the local school district have purchased Smart Boards, the course specifically focused on various features and tools of the Smart Notebook software, specifically Lesson Activity Toolkit (LAT) and Activity Builder addons. Based on these sessions, pre-service teachers were required to develop their own interactive differentiated activity for each subject, mathematics and science, using different LAT tools and/or Activity Builder. This assignment was completed by week seven. Amanda developed second grade activities for this assignment. Her mathematics activity used LAT category sort template with 12 addition statements that students could sort into true and false categories (Figure 4.2a). Her science activity used LAT pairs template with six pairs of animal pictures, so students could match the picture of the baby animal to an adult animal in a memory matching card game (Figure 4.2b). Both activities had built-in checks or feedback and were developed as self-assessments with questions that extended student thinking.
a. Mathematics activity

For both activities Amanda used role-playing scenarios to engage her students in an interactive game with visuals and immediate feedback, which was a new and different way of using technology. The tasks required students to make connections to previously learned topics. The questions showed her focus on extending student thinking to higher level. Both topics were selected from the standards-based curriculum and were age appropriate. However, these activities did not include inquiry tasks and did not provide opportunities for learning new material. Therefore, this artifact was scored at the Adapting level with score of 3.0 for all components. As class sessions continued to focus on differentiation strategies, such as providing

b. Science activity

Figure 4. 2. Smart activities for 2nd grade mathematics and science using Lesson Activity Toolkit templates in Smart Notebook software - editing view.
students with immediate feedback, letting students work at their own pace, providing visual support, etc., Amanda started to apply these ideas to digital content she was developing.

Sessions seven and eight focused on the role of technology to support explorations, inquiry-based tasks, and meaningful problem solving. During this time pre-service teachers were introduced to the interactive spreadsheets (excelets) and by the ninth session they developed their own dynamic mathematics explorations with self-assessment/practice using Excel developer tools and logic functions. Amanda developed a second grade mathematics activity for students to explore various combinations of coins producing a given value (Figure 4.3). She used spin buttons (up and down arrows) that allowed students to change the number of each coin that dynamically changed the total monetary value represented numerically and graphically. The activity also included extension with more challenging tasks and questions for student practice and self-assessment (Figure 4.4).

This artifact reflected the continued improvement in Amanda’s TPACK. In this activity students used technology to explore various ways of representing a given amount of money with coins, while the teacher provided students with guidance such as “make the needed amount by increasing or decreasing the number of coins by using the arrows.” The practice provided students with instant feedback. This use of technology by Amanda demonstrated that for Conception and Students components of TPACK she met one out of two criteria at the Exploring level, reaching a score of 3.5. However, graphical representation was not meaningful and did not provide support for student learning in this activity, the activity lacked questions to promote students’ reflection, and practice did not directly relate to the exploration. Therefore, for Curriculum and Instruction components Amanda remained at the Adapting level with a score of 3.0.
Figure 4. 3. Interactive activity for second grade mathematics lesson on money developed using Excel - dynamic exploration

<table>
<thead>
<tr>
<th>Instructions: Compare the coin amounts by using the symbols &gt;, &lt;, or =, then press enter.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Amount</strong></td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
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<td>5</td>
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</tbody>
</table>

Figure 4. 4. Interactive practice with immediate feedback

The improvement in Amanda’s scores could be attributed to the course continuing emphasis on using technology by students as an exploratory tool. By this time in the course, pre-service teachers experienced numerous examples of effective technology use in the classroom through published articles, classroom videos, and immersion lab experiences. In each course session, special emphasis was placed on the role of technology to support differentiation. It is
clear that Amanda applied what she learned to differentiate her Excel activity by providing a self-paced environment and enrichment tasks for her students. Immediate feedback is one of the strategies that research finds effective when teaching students with learning disabilities (DuPaul & Weyandt, 2006; Ford, 2013). Immediate feedback was discussed and modeled on a regular basis, and Amanda included self-assessment options with immediate feedback for her students in both, Smart activity and interactive Excel activity.

The sessions nine and ten introduced multimedia and hypermedia for planning, teaching, and engaging all students, including those with learning disabilities. For their next assignment pre-service teachers developed multimedia tutorial for student independent learning using PowerPoint. This assignment required use of hyperlinks and action buttons to develop easy to navigate tutorial for content learning as well as opportunities for student self-assessment. Amanda developed a fourth grade tutorial about the water cycle that included an interactive menu (Figure 4.5a), content slides (Figure 4.5b) with navigation buttons allowing students to move to different parts of the tutorial (Figure 4.5c). All slides were presented at age appropriate levels and were consistent with the standards-based curriculum. The quiz consisted of multiple choice text-based questions with immediate feedback and included an option to go back to read the content again if needed. (Figure 4.5d)

The tutorial enabled students to learn about the water cycle at their own pace and to self-assess themselves via an interactive quiz. The nonlinear structure of the tutorial with easy navigation accommodated different learning styles. Some students could read the content slides in order of presentation, others could start with the quiz and come back to the content when needed. Therefore, it met one of the criteria for Conception and Students components at the Exploring level with a score of 3.5. However, the content of the tutorial did not allow for deeper
learning and the quiz questions were a rote recall of information provided in the tutorial. Therefore, Amanda’s scores on Curriculum and Instruction components remained at the Adapting level with a score of 3.0.

At this point of the course Amanda started to meet some of the criteria at the Exploring level. As evident from her work, she began incorporating more opportunities for students to use technology for learning new material. Inan and Lowther (2010) suggest that as teachers’ exposure to instructional technology increases, the teachers’ feeling of readiness to integrate technology into instruction also increases. As the course explored tools supporting non-traditional approaches to teaching, Amanda became more comfortable allowing students to work at their own pace and not necessarily follow a sequential linear approach that is most commonly used in direct instruction.
Sessions eleven and twelve focused on using subject-specific emerging technology for problem-solving and inquiry, such as dynamic geometry software, Geometer’s Sketchpad and Vernier data collection technologies. They reflected on both, differentiation strategies and the opportunities for students to construct their own knowledge based on observations and generalizations. These two sessions provided pre-service teachers with the exposure to technology resources not commonly used in elementary schools that promote inquiry and problem solving opportunities for all students including those with learning disabilities.

During the same time, Amanda taught the lesson she developed in the beginning of the course. Analysis of Amanda’s video of teaching revealed that she made several changes to her lesson plan which improved her scores on all components except for Students. More specifically, she paused the BrainPop Jr. video several times during the whole class instruction to ask clarifying questions and to check for student understanding of the topic. This action represents meeting one of the criteria of Conception component at the Adapting level. The video was followed by several interactive activities in a whole class setting that enabled the teacher to assess student learning. The questions had immediate feedback and were sequenced from easy to more difficult providing opportunities for differentiation. This represents meeting both criteria of Instruction component at the Adapting level. Amanda also attempted to make an independent activity more meaningful by asking students to add information about their favorite stage of the life cycle of the plant to the image. This change represented the increase of Amanda’s score in Curriculum component to the Adapting level. However, students did not get any guidance on how to use technology and were not able to complete the tasks within the allocated time period, therefore the Student component of TPACK remained at the Accepting level.
Even though by this time in the course, Amanda demonstrated an ability to develop technology-based tasks for students at the Adapting level of TPACK as evident from the assessment of several artifacts, her teaching did not quite reach this level for Conception and Students components. Amanda was able to teach a better lesson than she planned as she applied to her teaching what she learned in the course during the six weeks since she developed her lesson plan. However, like most novice teachers Amanda struggled with classroom management (Ingersoll, 2012) preventing her from attending to her students learning. Focusing on herself rather than on students’ thinking is a “necessary and crucial element in the first stage of teacher development” (Kagan, 1990, p.155).

The thirteenth session of the course focused on using technology for assessment of student learning. Pre-service teachers reviewed different types of assessment and various technology tools available to the educators for assessment purposes. In-class discussion focused on the purpose of assessment in mathematics and science classrooms, and on the role of instant feedback in differentiation of instruction and assessment for students with learning disabilities.

During weeks 6-13, pre-service teachers were also working on developing their second technology-infused lesson plan. Amanda’s second lesson plan submitted during the 13th week was to teach the topic of counting money to the second-grade students. Amanda planned to start the lesson with a whole class read-aloud about different types of coins. Immediately after, she planned to assign students to small groups to engage in activities at four learning stations. Student groups would rotate through all four stations in order to learn about coins and solve word problems involving money. The two stations included hands-on coin manipulatives and worksheets, students were asked to do estimations and to create different combinations of coins to add up to the same value. The other two stations used computers while students played coin
memory game and used an interactive Excel activity she developed earlier in the course. In conclusion Amanda planned to have students share with the whole class what they learned. Analysis of this lesson resulted in a score of 4.0 (the Exploring level) for all four components. The larger part of instructional technology was used by the students as an exploratory tool to support problem solving involving currency. The tasks in the interactive Excel activity focused on the students’ mathematics conceptual understanding and supported student learning. The Excel activity was differentiated as students worked on tasks at various levels of difficulty, in a self-paced environment, and with immediate feedback. All technology-based activities were appropriate for the standards-based curriculum and for the grade level of students. Amanda planned to use various instructional strategies with technology: collaborative learning, discovery learning, learning centers, and formative assessment. Students were provided with multiple representations within technology tools, such as chart, table, visuals, etc. Amanda demonstrated the ability to plan for use of technology beyond traditional approaches, and digital materials that she developed promoted student reflection. The second lesson plan represented the highest level of TPACK that Amanda achieved by the end of the graduate course. The comparison of her first and second lesson plans showed a dramatic change in the way she used technology. It was no longer the teacher who delivered information to the students using technology (BrainPop Jr. video), but carefully designed exploration activity that students used to construct their own understanding of operations with money (interactive Excel activity).

Research shows that even when lesson plans call for student discovery and guided inquiry, often teachers fall back to a traditional environment to maintain control of student progression, to make sure they deliver the content, and to avoid behavioral problems (Ertmer et al., 2012). Amanda taught this lesson to a second grade class during the 14th week of the course.
The class had several students with learning disabilities and several English Language Learners. The analysis of her video showed that Amanda followed the lesson plan very closely. Each station was prepared for student use in advance, computers had website and Excel activities opened, and this facilitated a smooth transition between the stations. The timing of the lesson was well planned and executed. Student groups spent eight minutes in each station, which was sufficient to complete the tasks and not too long. Each student was able to complete all four stations. All students were fully engaged in the tasks, collaborating with each other, and reflecting on their task. Therefore, the taught lesson represented the Exploring level of Amanda’s TPACK for all components.

The last two sessions focused on the importance of teachers evaluating and reflecting on their own professional practice to support student learning. Pre-service teachers discussed the effective and ineffective ways that technology was used by experienced teachers in observed classrooms first, and then focused on self-reflection. Pre-service teachers watched videos of their own teaching to analyze their lessons against the principles of effective technology use (Goldenberg, 2000). While working in small groups, pre-service teachers discussed what they had learned, their challenges integrating instructional technology into their lessons, and shared possible ideas for improving the use of technology in their lessons. This analysis became part of their self-reflective papers submitted during the last (fifteenth) week of the course.

Amanda’s final reflection of the two taught lessons was analyzed through the lens of her external TPACK level (based on her artifacts) and her metacognition. According to Duffy et al. (2009) teachers’ metacognition is their reflection about what they already know or are in the process of learning. At the time of writing the final reflection, Amanda was at the Exploring level of TPACK; however, her reflection indicated that her metacognition (internal) TPACK
level was lower and did not reach the level of her abilities. As she reviewed her first lesson, Amanda recognized that selecting specific instructional technologies to teach her lesson should not be guided by motivation only. However, when reflecting on teaching her first lesson, Amanda failed to recognize that her use of Smart Board in a whole-class setting did not support learning for all her students, especially her students with disabilities.

*Smart Board was more than a motivation, it allowed for the students to engage with and understand complex science systems. It also allowed for positive learning for students with disabilities… the interactive screen was large enough to allow all learners to see and understand the content.*

When reflecting on teaching her second lesson, Amanda recognized the importance of providing students with digital materials for independent exploration. Differentiation methods used in her lesson were clearly identified and consistent with what she learned during the course: “*Students explored on their own*”, “*game provided instant feedback*”; however it was evident from her reflection, that she did not fully understand why some of used strategies were beneficial for her students learning: “*instant feedback allowed student to receive gratification for her hard work*”, “*technology was only used within 2 stations, because the class had many different types of learners.*”

Even though Amanda could teach with instructional technology at the Exploring level, she was not able to recognize her own shortcomings and it was evident that she did not fully understand when technology use in her lessons was effective or ineffective and whether technology supported or did not support student learning.
TPACK Transfer Analysis

This study analyzed one technology-based lesson plan and a video of teaching this lesson provided by Amanda during her first year of teaching, approximately one year after she completed the TPACK-based graduate course. The lesson focused on the fourth grade science topic of hurricanes. Based on the video of teaching, Amanda followed her lesson plan very closely. Therefore, the analysis of both the lesson plan and the video is combined. In this lesson the larger part of the technology use was by the students in order to research famous hurricanes, which meets one of the criteria for the Conception component at the Exploring level. However, even though the student activity focused on scientific tasks with connections, students were not really doing science. They were mostly gathering information, which meets criteria for the Conception component at the Adapting Level. Therefore, in Conception, Amanda demonstrated the Adapting level of TPACK with score of 3.5. In this lesson technology tools were used for learning new knowledge - in a whole class setting, and in small groups while students were gathering information about specific hurricanes. Students chose the hurricane they wanted to explore and their own Internet resources based on the Google Search. This design meets criteria of the Adapting level with the score 3.0 for the Students component. Amanda replaced reading from the textbook with the PowerPoint presentation. In the same way, student research on the Internet was a replacement of reading printed materials about hurricanes. Technology was clearly aligned with curriculum goals, and its use was appropriate for the topic of the lesson, which met one criteria at the Adapting level and one criteria at the Exploring level with a score of 3.5 for the Curriculum component. Finally, Amanda used various instructional strategies: direct instruction at the beginning of the lesson, student read-aloud the information on the slides, and collaborative learning with flexible grouping. However, even though digital materials were
built around learning objectives, they did not promote student reflection and there were no higher-order questions to promote student critical thinking. Therefore, the lesson plan and teaching represented the Adapting level with score 3.5 for the Instruction component.

This analysis showed that Amanda’s TPACK level during her first year of teaching decreased compared to her highest achieved level in the graduate course. The analysis showed that Amanda developed the Adapting level of TPACK by the seventh week of the course and maintained it mostly through the rest of the course, and only in the last two weeks of the course she was able to demonstrate TPACK at the Exploring level. The fact that she retreated back to the Adapting level in her first year teaching shows that she transferred TPACK that she was able to retain over a longer period of time, and the knowledge and skills of teaching at the Exploring level were too new, not well established, and were not fully transferred.

**Phone Interview.** In order to analyze factors that could have affected Amanda’s transfer of TPACK, the phone interview with Amanda was conducted at the beginning of her second year of teaching. The semi-structured and open-ended questions were used to address the interviewee’s past experience while taking the TPACK-based graduate course, her comfort level with technology, her views toward technology integration, and elements that influenced her teaching practices with technology. The phone interview was recorded, transcribed, and the common themes in relation to the research questions were identified for analysis. Mohan’s (2007) concept of a social practice was used to organize the reflection and interview data into smaller units, units of meaning (UoMs) for data analysis. The themes were organized in relation to the research question: What are the internal and external factors affecting TPACK transfer for this teacher? Based on the interview two external factors (access to technology and school
support) and two internal factors (teacher’s attitude towards using technology and preparedness -
teacher’s comfort with using technology were identified.

One year after taking the course, Amanda was teaching in a first grade Integrated
Collaborative Teaching (ICT) classroom in a New York City title I elementary school. As a first
year teacher, Amanda had very limited access to technology: she had access to a SmartBoard and
two computers. She was able to use this technology, but she wished she had access to more tools.
When asked how she used technology in her current classroom, Amanda responded: *SmartBoard
lessons, Good Morning message using PowerPoint with an overview of the day, Interactive
textbook - Go Math curriculum, BrainPop Jr. videos and activities.* During the lesson that was
used in this study, the Internet was not working properly, there was no access to the BrainPop Jr.
video. and a Smart Board in the classroom did not function properly. Therefore, Amanda was not
able to implement technology into this lesson the way she planned. Despite her frustration with
the limited access to technology and lack of technical support, she expressed her hopes to
incorporate more technology in the future. This factor (access to technology) could have led to
regression of her level of TPACK during her first year of teaching compared to the level
achieved by the end of the graduate pedagogy course. These findings are supported by research
showing that when schools and teachers do not have adequate access to technological resources
in the classroom, attitudes of teachers are less positive towards the use of technology and they
tend to use technology to a lesser degree as they educate their students (Kusano et al., 2013).
Therefore, the availability and working condition of available instructional technology in schools
is one of the external factors that could affect TPACK transfer. Teacher attitudes could be one of
the internal factors that might affect TPACK transfer.
According to Amanda, her school administration did not put any emphasis on using instructional technology, the technology was not widely accessible, and there were no other teachers using technology. There was no feedback from peers on her lesson plans with technology, while in graduate course she had an extensive feedback from the course instructor and from her peers before teaching her technology-based lesson. These external factors could have been the cause of Amanda’s regression from the Exploring to the Adapting level of TPACK (Hermans, Tondeur, van Braak & Valcke, 2008).

Despite lack of support and limited access to instructional technology in her school, Amanda’s interview demonstrated that she was very enthusiastic about integration of instructional technology into her teaching, and her attitudes could have been the factor that helped her to sustain the Adapting level of TPACK: *Very confident very motivated to use technology*. Studies show that a teacher who possesses positive attitudes toward Information and Communication Technology is more motivated to integrate it into his or her teaching practices (Cavas et al., 2009).

During her interview, Amanda acknowledged the benefits of learning specific technology tools and their roles in supporting student learning in the graduate course that she was able to use later on: *I used the PowerPoint project in student teaching*. She also identified that some of the tools were challenging for her to learn in allotted amount of time: “*Challenge was the Excel project, difficult to understand.*

The interview revealed that after taking the graduate course Amanda felt well prepared and comfortable to use instructional technology in her future classroom. Consistent with Howley, Wood and Hough (2011) research, teacher’s perceived level of preparedness for using technology is related to technology integration in the classroom. Amanda also acknowledged
that some instructional strategies she learned in her graduate course were very helpful and she wished the teacher preparation program offered more real world support such as curriculum, school resources, more useful applications of skills and strategies, more of a connection, real-life applicability. She felt motivated to use some of the tools she learned during the course (e.g. multimedia tutorial, Smart activity). Moreover, she confirmed that she used multimedia tutorial developed during the graduate course in her teaching.

Analysis of Learning Trajectory

The purpose of this section is to present the analysis of Amanda’s learning trajectory from a TPACK-based graduate pedagogy course to the first year of teaching. Table 4.2 shows Amanda’s scores for each component of TPACK and total TPACK based on assessment of artifacts analyzed earlier in this chapter.

Table 4.2 Teacher’s learning trajectory for components and total TPACK (week represents time of completion)

<table>
<thead>
<tr>
<th>Week</th>
<th>Artifact</th>
<th>Conception</th>
<th>Students</th>
<th>Curriculum</th>
<th>Instruction</th>
<th>Total TPACK</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Lesson Plan 1</td>
<td>2.0</td>
<td>2.0</td>
<td>2.5</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>6</td>
<td>Blog</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>7</td>
<td>Smart Activity</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>9</td>
<td>Interactive Excel</td>
<td>3.5</td>
<td>3.5</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>11</td>
<td>Multimedia Tutorial</td>
<td>3.5</td>
<td>3.5</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>12</td>
<td>Video Lesson 1</td>
<td>2.5</td>
<td>2.0</td>
<td>3.0</td>
<td>3.0</td>
<td>2.0</td>
</tr>
<tr>
<td>13</td>
<td>Lesson Plan 2</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>14</td>
<td>Video Lesson 2</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>60</td>
<td>First year lesson plan</td>
<td>3.5</td>
<td>3.0</td>
<td>3.5</td>
<td>3.5</td>
<td>3.0</td>
</tr>
<tr>
<td>62</td>
<td>First year teaching video</td>
<td>3.5</td>
<td>3.0</td>
<td>3.5</td>
<td>3.5</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Amanda’s scores for each component of TPACK changed similarly - scores gradually increased throughout the semester of graduate pedagogy course and then regressed slightly during her teaching, with the exception of her teaching first lesson. However, during weeks 7-13 there were distinct differences in changes for Conception and Students components compared to changes in Curriculum and Instruction components. During these weeks, Amanda was transitioning from Adapting level to Exploring. This transition is transformative in its nature since it requires teachers to change the way they envision teaching and learning. This explains the fact that during weeks 9-11 Amanda’s scores for Conception and Students were higher than her scores for Curriculum and Instruction components. However, in practice it is more difficult to implement these new ideas into the classroom, especially for a pre-service teacher who does not have the experience or skills to manage a classroom. Therefore, her scores for Conception and Students dropped to the Accepting level during week 12, when she was teaching her first lesson plan. At the same time her scores in the Curriculum and Instruction components remained at the Adapting level and this shows that Amanda still did not fully grasp the ideas of the inquiry-based learning that would explicitly promote student reflection. Research shows that teaching through inquiry is very challenging for new teachers (National Research Council, 2012) and it takes time and experience to build the inquiry competence (Aulls, & Shore, 2008). Although pre-service teachers mostly can distinguish between effective traditional and effective inquiry instruction, it is difficult for them to bridge subject-matter knowledge with pedagogy and to use content knowledge in ways that help all students as inquirers (Aulls et al., 2016, p.3). It took Amanda almost a full semester before she was able to include inquiry tasks with technology in her lesson. Being constantly pushed by her instructor, being provided with constant feedback and being encouraged to apply ideas she learned in the course, might have helped Amanda to
reach the Exploring level for all components of TPACK by the thirteenth week of the course. The semester ended two weeks later and there was no time to for her to reinforce and retain these newly acquired skills, especially since there was no support in her further coursework or teaching for effective use of technology. One year later being a new teacher Amanda developed and taught a lesson that did not include inquiry tasks. Her TPACK scores of 3.5 for Conception, Curriculum and Instruction showed that even though Amanda did not feel comfortable using inquiry-based activities with technology in her classroom, she was confidently using various instructional strategies. However, her score of 3.0 in the Students component indicate that she returned back to more controlled environment for her students when learning with technology.

In conclusion, at the end of the course, Amanda reached the Exploring level of TPACK (her personal highest) to slightly regress back to the Adapting level year later as she started her teaching. For a first year teacher, sustaining the Adapting level of TPACK is a great accomplishment. Research shows that many experienced teachers use technology at the Adapting level (Niess, 2016, McBroom, Jiang, Sorto, White & Dickey, 2016).

**Solutions and Recommendations**

According to the National Research Council (2000), time and practice are among the factors affecting a person’s ability to retain and use newly learned information. Crede and Kuncel (2008) suggest that if a newly acquired skill is not reinforced by practical follow-up assessments, most of that skill will be lost within a time proportional to the time it took to learn that skill. Amanda reached the Adapting level of TPACK by the seventh week of the course and maintained it for eight weeks, while she only achieved the Exploring level of TPACK during the
last two weeks of the course. She did not have time during her college coursework to practice the
skills necessary to sustain the Exploring level of TPACK, and therefore she regressed to the
Adapting level during her first year teaching.

This course was the only technology-based course in the graduate program. In order to
help pre-service teachers to develop higher levels of TPACK earlier in their graduate program,
TPACK development should be integrated in all pedagogy courses, including student teaching
practicum. Changes could also be made within a single course. In the graduate course considered
in this study, technology-based activities and lesson plans were assigned as unrelated single
assignments. The reflection on teaching was assigned at the end of the course, so there was no
scaffolding throughout the course to develop the reflective practices and metacognition
important to sustaining TPACK level.

To increase new teachers’ metacognition level, more attention and time during the course
should be devoted to the importance of reflection and the teachers’ ability to self-assess and self-
reflect. Assignments could be combined into a teaching portfolio that pre-service teachers
complete over the length of the course. Additional requirements could include pre-teaching and
post-teaching reflections with focused questions to foster reflection and self-assessment. To
support development of metacognition, TPACK as criteria should be integrated more rigorously
throughout the course. While writing their reflections, pre-service teachers should support their
analysis with current research, instead of their own opinions. In order to help pre-service teachers
to develop their metacognition, educators can provide specific questions for analysis and
reflection. Work on the portfolio would also allow pre-service teachers to go back and revise
their work as needed. For example, developing the second lesson plan would involve several
chronological stages, that could support teachers’ TPACK development: development of the
lesson plan draft, educator’s feedback on the draft, pre-service teachers’ pre-teaching reflection, teaching lesson with video recording, post-teaching reflections, video analysis, analysis of students artifacts, partner assessment of lesson collection, reflection on partner analysis, reflection on the whole process, and refinement of the lesson plan. In order to increase the level of the preparedness of pre-service teachers, the course would include additional lab time with instructor’s support and guidance. Technology-based assignments could be developed by the pre-service teachers during these labs that will provide immediate feedback from the instructor and higher quality of work, while reducing anxiety and discomfort with new technological tools, and therefore improving pre-service teachers’ attitudes towards technology.

While the schools of education have no control over teaching context of their graduates, they can still provide support and offer mentoring to their graduates. If a novice teacher does not have any support in their new schools, one possible solution would be establishing partnership relationship with the schools, to provide opportunities for new teachers to communicate with mentors and their peers.

**Future Research Direction**

The study raised an important question for teacher educators. How should technology be integrated into teacher preparation programs to develop and sustain higher levels of pre-service teachers’ TPACK and promote pre-service teachers’ positive attitudes towards technology integration into teaching? Further research is needed to analyze this question.
Conclusion

The purpose of this case study was to analyze the TPACK development and a learning trajectory of a single pre-service special education elementary school teacher during their TPACK-based graduate pedagogy course and TPACK transfer from the graduate level course to the teaching during induction year. The graduate pedagogy course played a critical role in developing pre-service teacher’s TPACK, especially the part of the course that introduced them to various technology tools, along with skills and strategies on how to use these tools for learning mathematics and science in an elementary school setting and how to differentiate technology-based tasks for students with learning disabilities. It was also noted that a teacher’s enthusiasm and positive attitude towards integrating instructional technology could help the teacher to sustain or possibly even increase her TPACK level. It is reasonable to suggest that having positive attitudes toward instructional technology, and with additional support (e.g. professional development, school technology and administrative support), novice teachers have possibilities to increase their TPACK level. On the other hand, a lack of support for technology integration in the classroom, or a lack of encouragement or incentives may result in teachers decrease of the TPACK level.
References


CHAPTER 5. GENERAL SUMMARY

This chapter presents a summary of studies included in this dissertation. Findings are discussed through the lens of the Technological Pedagogical Content Knowledge (TPACK) framework. Implications for further research and practice are suggested.

“Integration [of technology] is defined not by the amount or type of technology used, but by how and why it is used” (Earle, 2002, p.8). Instructional technology when used appropriately in the classroom, can support teachers to deliver the content and implement instructional practices in more effective ways to support learning of all students. However, most pre-service teachers have little specific knowledge or associated skills with respect to the use of technology for teaching and learning (Tearle & Golder, 2008).

The research that contributed to this dissertation addressed some of the existing gaps in the current studies that investigate the development and transfer of TPACK of pre-service and in-service elementary school special education teachers. The first study analyzed development of TPACK of pre-service elementary special education teachers. The results of the first study led to two different questions: 1) What is the relationship between basic TPACK domains: TK (Technological Knowledge), PK (Pedagogical Knowledge) and CK (Content Knowledge) and the TPACK? and 2) what happens with the TPACK when pre-service teachers continue their professional practice? (TPACK transfer)? The next two studies address these two questions.
The first chapter, “Introduction,” provided an extensive literature review on factors influencing teachers’ successful technology integration (educational policy, teacher preparation programs, teachers’ beliefs and attitudes towards using technology in their classrooms). Benefits of using instructional technology in the classroom were discussed with the main focus on the special education teachers using instructional technology in elementary inclusive classrooms. Chapter one also introduced the concept that framed this dissertation: Technological Pedagogical and Content Knowledge (TPACK) and the instrument used in all studies for external assessment of teachers’ TPACK: *TPACK Levels Rubric* (Lyublinskaya & Tournaki, 2012). In order to evaluate the effectiveness of teacher education programs, TPACK domains need to be precisely defined, and reliable instruments need to be available for “measuring and assessing TPACK in a variety of context” (Shinas et. al., 2013, p.340). The analysis of the literature revealed various existing instruments used to evaluate the basic domains of the TPACK framework (e.g. self-reported surveys, questionnaires, interviews, analysis of teaching artifacts and classroom observations); however, it was still not clear there were no studies that analyzed whether the basic domains of the TPACK framework affect the teachers’ TPACK and whether TPACK domain can be measured independently from the basic domains. Finally, the existing studies focused on pre-service teachers’ knowledge transfer were reviewed. Findings revealed that although it is crucial to understand how teachers transfer their knowledge from the teacher preparation course to their teaching practice, there is very limited research on transfer of teachers’ TPACK. Based on the analysis of the literature, therefore, the following themes emerged as needing more research: 1) pre-service special education teachers’ TPACK development, 2) assessment of pre-service teachers’ TPACK including instruments needed for
external assessment, and 3) pre-service teachers’ TPACK transfer into their elementary special-education classroom practice.

The study presented in the second chapter focused on analyzing whether the TPACK-based graduate level course affected TK, PK, CK and TPACK of pre-service special education elementary teachers (Kaplon-Schilis & Lyublinskaya, 2015). The objective of the graduate course was to develop pre-service elementary special education teachers’ TPACK for teaching mathematics and science to all students. Findings of the study reveal statistically significant gains in pre-service teachers’ TPACK which indicated change in teachers’ understanding of how to use technology in the classroom upon completing of the course. However, there were no significant changes in pre-service teachers’ TK, PK and CK scores. The study raised a question whether the basic domains of TPACK framework (TK, PK and CK) are independent of TPACK domain.

The third chapter focused on exploring whether TK, PK, CK (in mathematics and science) and TPACK are independent constructs in the TPACK framework (Kaplon-Schilis & Lyublinskaya, 2017). The purpose of this study was first to develop instruments for assessment of each basic theoretical TPACK domain independently and second to analyze whether basic domains (TK, PK, and CK) are predictors of TPACK.

Exploratory and confirmatory factor analysis of the developed instruments suggested that TPACK domain is independent from its basic domains. Further analysis using multiple linear regression showed that there were no significant correlations observed between TPACK and TK, PK and CK (in mathematics and science). The testing of the model also confirmed that the basic domains of TPACK were not predictors for TPACK domain.
The fourth chapter “Development and Transfer of TPACK from Pre-Service to In-Service Experience for a Special Education Elementary School Teacher - Case Study” utilized a case study approach to investigate whether pre-service teacher’s TPACK developed during the graduate level course, transfers into their classroom practice (Kaplon-Schilis & Lyublinskaya, 2018). The purpose of this case study was to analyze the TPACK development and a learning trajectory of a single pre-service special education elementary school teacher during her TPACK-based graduate pedagogy course and TPACK transfer from the graduate level course to the teaching during her induction year. The graduate pedagogy course played a critical role in developing pre-service teacher’s TPACK, especially part of the course that introduced the pre-service teacher to various technology tools along with skills and strategies on how to use these tools for teaching mathematics and science in elementary school setting. Findings suggested several internal and external factors affecting a teacher’s transfer of TPACK from her pre-service to in-service teaching experience. It was noted that teacher’s enthusiasm and positive attitude towards integrating instructional technology could help the teacher to sustain her TPACK level. On the other hand, lack of support for technology integration in the classroom, lack of encouragement or incentives may result in teacher’s decrease of the TPACK level.

The three studies completed within this research project provided an analysis of the relevant background literature and explored the posted research questions. In general, these studies suggest that: 1) a well-designed TPACK framework-based pedagogy course can help to develop and improve pre-service elementary special education teachers’ TPACK, 2) the basic domains of teacher knowledge are independent from the TPACK domain and they are not predictors of teacher’s TPACK level, 3) the transfer of TPACK from college classroom to
teaching might be affected by TPACK learning trajectory in the college classroom, teacher’s attitudes towards technology, and various school factors.

Limitations and Further Studies

The study described in chapter two followed a single group pre-posttest design, which naturally leads to the limitation due to a lack of a control group. Since the study was conducted in a required graduate level pedagogy course and all students enrolled in a Master's program in Special Education had to take this course in order to complete the program, it was impossible to have a control group. Since the population consists of the specific group of graduate level pre-service teachers, the further studies could focus on different population (e.g. pre-service secondary school special-education teachers, or general education elementary school pre-service teachers) to evaluate how TPACK framework-based courses affect pre-service teachers’ TPACK development.

The second study limitation is the relatively small sample size (N=116). Study findings need to be further confirmed with larger sample. The instruments were designed with a specific purpose in mind: examining basic knowledge of preservice elementary school special education teachers’ and their development of TPACK, further studies could focus on validating the instruments to measure TPACK domains in different setting and context (e.g. elementary school general education teachers). Another limitation of this study is that only the basic domains of teacher knowledge and their relationship to the TPACK domain were investigated. The further study could focus on exploring relationship between all seven domains of the TPACK framework.
The limitation of the third study is that the study is not generalizable. Only one pre-service teacher was selected for the case study, and even though there are no set guidelines for “needed sample size in case studies” (Yin, 2012, p.9), further study could analyze the work of more pre-service teachers (eight to ten) to search for patterns in teachers’ TPACK transfer.

**The practical applications**

The findings in these studies led to some practical applications. First, the graduate pedagogy course has been redesigned to better prepare the pre-service elementary school special education teachers to use technology in their future classrooms. Some of the changes include: assignments combined into a teaching portfolio over the length of the course instead of technology-based activities developed as unrelated single assignments; pre-teaching and post-teaching reflections, with focused questions, written over the length of the course rather than at the end of the course; pre-service teachers reflections supported with current research instead of their own opinions; development of the second lesson plan divided into several chronological stages to support teachers’ TPACK development.

The ongoing analysis of the TPACK Levels rubric led to a need for a revision of the original rubric (Kaplon-Schilis & Lyublinskaya, 2018, study not included in the dissertation). The revised rubric includes more distinct indicators for each level and each component of TPACK to provide guidelines for educators using the TPACK Levels rubric in assessing pre-service and in-service teachers’ TPACK level.
Significance and Implications for Practice

According to the results of the studies presented in this dissertation, the TPACK framework-based course leads to a significant increase in pre-service elementary school special education teachers’ TPACK. Therefore, the TPACK framework could serve as a conceptual framework to design courses in various teacher preparation programs and across other disciplines, to prepare pre-service teachers to effectively integrate technology in their future classrooms. The findings of these studies could inform teacher educators of what instructional strategies support pre-service teachers’ TPACK development and can guide them to design courses that aim to improve TPACK of future teachers.

The significance of the study presented in chapter 3, is that to the best of authors’ knowledge this is the first study that developed and validated the instrument for external assessment of TK, PK, CK (in mathematics and science), of preservice elementary special education teachers. Furthermore, the study provided initial evidence that TPACK as measured by TPACK Levels Rubric is an independent construct from TK, PK and CK in the context of integrating technology into teaching mathematics and science by special education pre-service elementary school teachers. Further studies are needed to confirm independence of these domains with different populations.

According to the case study (chapter 4) the pedagogy course played a critical role in developing pre-service teacher’s TPACK. However, in order to help pre-service teachers to transfer the knowledge developed during the course, the study suggests that TPACK needs to be developed earlier in their graduate program. TPACK development should be integrated in all pedagogy courses, including student teaching practicum. Authors identified also teachers’ attitudes towards technology use in the classroom as a possible contributing factor to TPACK
transfer. Moreover, this case study suggests that as pre-service teachers experience added value of TPACK in their preparation, their attitudes toward using technology could improve. Therefore, further studies are needed to analyze relationship between exposure to technology in various courses and attitudes towards technology.

The purpose of this case study was to analyze the TPACK development and a learning trajectory of a single pre-service special education elementary school teacher during their TPACK-based graduate pedagogy course and TPACK transfer from the graduate level course to the teaching during induction year. It was also noted that a teacher’s enthusiasm and positive attitude towards integrating instructional technology could help the teacher to sustain or possibly even increase her TPACK level. It is reasonable to suggest that having positive attitudes toward instructional technology, and with additional support (e.g. professional development, school technology and administrative support), novice teachers have possibilities to increase their TPACK level. On the other hand, a lack of support for technology integration in the classroom, or a lack of encouragement or incentives may result in teachers decrease of the TPACK level.

Overall, future studies will focus on: 1) determining the factors that contribute to pre-service teachers’ TPACK development, 2) including exploring relationship between all seven domains of the TPACK framework, 2) analyzing the role of the external and internal factors in the process of TPACK transfer, 3) revising and validating the TPACK Levels rubric.
References


Kaplon-Schilis, A., & Lyublinskaya, I. (2015, March). Exploring changes in technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK) and TPACK of pre-service, special education teachers taking technology-based pedagogical course. In *Society for Information Technology & Teacher Education International Conference* (pp. 3296-3303). Association for the Advancement of Computing in Education (AACE).


### APPENDIX A: TPACK LEVELS RUBRICS

**TPACK Levels Rubric for Instructional Technology Applications**

<table>
<thead>
<tr>
<th>TPACK Components</th>
<th>Recognizing (1)</th>
<th>Accepting (2)</th>
<th>Adapting (3)</th>
<th>Exploring (4)</th>
<th>Advancing (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>An overarching conception about the purposes for incorporating technology in teaching subject matter topics.</td>
<td>Instructional technology is used for motivation, rather than actual subject matter development. All learning of new ideas presented by the teacher mostly without technology.</td>
<td>Technology-based activities do not include inquiry tasks. Technology procedures concentrate on teacher demonstration and practice.</td>
<td>Teacher is one who is using instructional technology in a way that is new and different from teaching without this technology and used for learning new knowledge by students.</td>
<td>Larger part of instructional technology use is by students who explore and experiment with it for new knowledge and for practice.</td>
<td>Instructional technology tasks provide students with deeper conceptual understanding of mathematics and science and their processes.</td>
</tr>
<tr>
<td>Technology-based activities do not include inquiry tasks. Technology procedures concentrate on drills and practice only.</td>
<td>Instructional technology is used for motivation, rather than actual subject matter development. Larger part of technology use is for demonstrations, which include presenting new knowledge.</td>
<td>Technology-based activities include inquiry tasks. Technology procedures concentrate on mathematical or scientific tasks with connections and on inquiry activities that use or develop connections.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Teacher is one who is using instructional technology in a way that is new and different from teaching without this technology and used for learning new knowledge by students.</td>
<td></td>
<td></td>
<td>Technology-based activities include inquiry tasks. Technology procedures concentrate on mathematical or scientific tasks with connections and doing mathematics or science – and on inquiry activities that use or develop connections.</td>
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<td>Technology-based activities include inquiry tasks. Technology procedures concentrate on mathematical or scientific tasks with connections and doing mathematics or science – and on inquiry activities that use or develop connections.</td>
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</thead>
<tbody>
<tr>
<td>Knowledge of students’ understandings, thinking, and learning in subject matter topics with technology</td>
<td>Instructional technology is used primarily for student practice. Digital materials do not present any new material, and only provides space for applications and drills. Teacher sees the technology as a motivational tool for student rather than a learning tool. Digital materials mirror the structure of the textbook presentation of mathematics or science without active explorations.</td>
<td>Instructional technology is mostly used for teacher demonstrations or teacher-led student-follow work with technology; it is rarely used for students’ independent explorations. Teacher focuses on students’ thinking of mathematics while students are using instructional technology on their own – both for learning new knowledge and review of prior knowledge. Digital materials provide an environment for students to do mathematics or science with teacher guidance.</td>
<td>Teacher focuses on students’ mathematics or science conceptual understanding and serves as a guide of student learning with technology, not a director. Digital materials provide an environment for students to deliberately take mathematically or scientifically meaningful actions on objects. Teacher guidance is necessary in order for students to see the mathematically or scientifically meaningful consequences of those actions.</td>
<td>Instructional technology focuses on students’ mathematics or science conceptual understanding and serves as a guide of student learning with technology, not a director. Digital materials provide an environment for students to deliberately take mathematically or scientifically meaningful actions on objects. Teacher guidance is necessary in order for students to see the mathematically or scientifically meaningful consequences of those actions.</td>
<td>Teacher facilitates students’ high level thinking with instructional technology. Digital materials provide an environment for students to deliberately take mathematically or scientifically meaningful actions on objects and to immediately see the mathematically or scientifically meaningful consequences of those actions.</td>
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</tbody>
</table>

### TPACK Levels Rubric for Instructional Technology Applications

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</tr>
</thead>
<tbody>
<tr>
<td>Knowledge of curriculum and curricular materials that integrate technology in learning and teaching subject matter topics</td>
<td>Teacher does not use instructional technology for learning mathematics or science. Instructional technology if used is not aligned with one or more curriculum goals. Teacher has difficulty in identifying topics in mathematics or science curriculum for including instructional technology as tool.</td>
<td>Teacher uses standard approach to the curriculum topics with instructional technology being used as add-on. Instructional technology is partially aligned with one or more curriculum goals. Teacher only adapts experiences that he/she has personally experienced in his/her learning. Instructional technology is aligned with one or more curriculum goals. Teacher chooses topics from school mathematics or science curricula; however, technology use is not always appropriate for the chosen curriculum topics.</td>
<td>The instructional technology is used as a replacement for non-technology based tasks in a traditional curriculum approach. Teacher only adapts experiences that he/she has personally experienced in his/her learning. Instructional technology is aligned with one or more curriculum goals. Teacher chooses topics from school mathematics or science curricula; however, technology use is not always appropriate for the chosen curriculum topics.</td>
<td>Teacher envisions on his/her own as to how curriculum might be taught with the technology. Students are given problem solving tasks with instructional technology and are asked to expand mathematics or science ideas on the basis of technology explorations. Technology is aligned with curriculum goals. Teacher chooses important topics of school mathematics or science curricula and technology use is appropriate for the chosen curriculum topics.</td>
<td>Teacher uses instructional technology in a fully constructive way, including tasks for development of higher level thinking and deepening understanding of mathematics or science concepts. Teacher challenges the traditional curriculum - engaging students in learning quite different topics with the technology and eliminating some of the topics that have traditionally been taught. Instructional technology is strongly aligned with curriculum goals. Teacher chooses essential topics of school mathematics or science curricula. Technology use is effective for the chosen curriculum topics.</td>
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<tr>
<td>Knowledge of instructional strategies and representations for teaching and learning subject matter topics with technologies</td>
<td>Teacher focuses on how to use instructional technology rather than how to explore mathematics or science ideas, using teacher-directed lectures followed by student practice.</td>
<td>The instructions are teacher-led. Teacher structures lesson plan with limited student explorations with instructional technology. Digital materials are not built around learning objects and do not promote student reflection.</td>
<td>Teacher uses deductive (teacher-directed) approach to teaching with instructional technology to maintain control of the progression of the activities. Digital materials are built around learning objects but do not promote student reflection – especially the posing of questions for sense-making.</td>
<td>Teacher uses various instructional strategies (deductive and inductive) and focuses on students thinking about mathematics. Teacher’s use of instructional technology is beyond traditional approaches to curricular topics. Digital materials are built around learning objects and must explicitly promote student reflection – especially the posing of questions for sense-making.</td>
<td>Teacher focuses on students’ hands-on and experimentation of new mathematics or science ideas with instructional technology, and focuses on conceptual development. Digital materials are built around learning objects and must explicitly promote student reflection – especially the posing of questions for sense-making and reasoning, including explanation and justification.</td>
</tr>
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