Technological Content Knowledge and Technological Pedagogical Knowledge in Secondary Science Teachers: A Mixed Methods Analysis

Stefanie Graban

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TECHNOLOGICAL CONTENT KNOWLEDGE AND TECHNOLOGICAL PEDAGOGICAL KNOWLEDGE IN SECONDARY SCIENCE TEACHERS: A MIXED METHODS ANALYSIS

A Dissertation
Submitted to the School of Education

Duquesne University

In partial fulfillment of the requirements for the degree of Doctor of Education

By
Stefanie Graban

December 2022
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Stefanie Graban

2022
TECHNOLOGICAL CONTENT KNOWLEDGE AND TECHNOLOGICAL PEDAGOGICAL KNOWLEDGE IN SECONDARY SCIENCE TEACHERS: A MIXED METHODS ANALYSIS

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ABSTRACT

TECHNOLOGICAL CONTENT KNOWLEDGE AND TECHNOLOGICAL PEDAGOGICAL KNOWLEDGE IN SECONDARY SCIENCE TEACHERS: A MIXED METHODS ANALYSIS

By

Stefanie Graban

December 2022

Dissertation supervised by Dr. Karen Levitt

Teachers in K-12 education are increasingly using technology in their courses. However, teachers may struggle to implement technology effectively in their specific subject areas. Existing research demonstrates that there was a need to better support in-service science teachers’ technological content knowledge. Accordingly, the purpose of this practitioner research study was to examine how, why, and to what extent in-service secondary science teachers report using technology as part of instructional practices. The TPACK framework was used as the theoretical lens for a mixed methods study exploring secondary science teachers’ technological pedagogical knowledge (TPK) and technological content knowledge (TCK). Multiple data sources were collected from science teachers in four school districts in south-central Pennsylvania. Confidence intervals determined that there was some difference between the groups studied, but the
sample size was too small to determine if it was a significant difference. Qualitative analysis demonstrated that the participants already used technology in their classes, but they would like to learn more.

The findings from this study can inform technology-based professional development intended to better support in-service science teachers.

*Keywords*: instructional technology, TPACK, TPK, TCK, science education
DEDICATION

This dissertation is dedicated to my parents, Ted and Peggy Graban, who passed away during my doctoral journey. They always pushed me to reach further and higher. I know you will not be there to see me graduate “in my Harry Potter robe,” but I will most definitely make it to that graduation stage. I love you and miss you every day.
ACKNOWLEDGEMENT

I would like to acknowledge my dissertation committee who have all been extremely helpful in this dissertation process. Thank you for always being patient with me as I learn how to be a proper academic scholar. I would also like to thank all my professors and teachers, from my first day of kindergarten to my doctoral committee, who have shaped me into the person that I am today. I would like to thank my fellow doctoral students for all their support and encouragement. I would like to thank my friends, family, and coworkers who have supported me throughout this experience, even though they sometimes doubt my sanity. Lastly, I would like to thank my parents and my sisters, who have always been my biggest cheerleaders.
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>iv</td>
</tr>
<tr>
<td>DEDICATION</td>
<td>vi</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td>vii</td>
</tr>
<tr>
<td>List of tables</td>
<td>xii</td>
</tr>
<tr>
<td>List of figures</td>
<td>xiii</td>
</tr>
<tr>
<td>Chapter 1</td>
<td>1</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Problem Statement and Significance</td>
<td>3</td>
</tr>
<tr>
<td>Research Questions</td>
<td>4</td>
</tr>
<tr>
<td>Limitations</td>
<td>5</td>
</tr>
<tr>
<td>Delimitations</td>
<td>5</td>
</tr>
<tr>
<td>Definition of Terms</td>
<td>6</td>
</tr>
<tr>
<td>Conclusion</td>
<td>8</td>
</tr>
<tr>
<td>Chapter 2 Literature Review</td>
<td>9</td>
</tr>
<tr>
<td>Theoretical Framework: TPACK</td>
<td>9</td>
</tr>
<tr>
<td>Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK)</td>
<td>12</td>
</tr>
<tr>
<td>Teaching with Technology</td>
<td>13</td>
</tr>
<tr>
<td>Science Teachers and TPACK</td>
<td>15</td>
</tr>
<tr>
<td>The Needs of Small School Districts</td>
<td>20</td>
</tr>
<tr>
<td>Summary</td>
<td>21</td>
</tr>
<tr>
<td>Chapter 3 Research Design and Methods</td>
<td>23</td>
</tr>
<tr>
<td>Explanatory-Sequential Mixed Methods Design</td>
<td>23</td>
</tr>
<tr>
<td>Research Questions</td>
<td>24</td>
</tr>
<tr>
<td>Theoretical Framework</td>
<td>24</td>
</tr>
<tr>
<td>Research Context</td>
<td>25</td>
</tr>
<tr>
<td>Research Sample</td>
<td>26</td>
</tr>
<tr>
<td>Instruments</td>
<td>29</td>
</tr>
</tbody>
</table>
Dynamic nature between technological content knowledge (TCK) and technological pedagogical knowledge (TPK) .............................................................. 63

Mixed methods results ........................................................................................................ 70

How secondary science teachers use technology in their classrooms. ..... 70

Why secondary science teachers use technology in their classrooms. ..... 71

To what extent do secondary science teachers report using technology in their classrooms. ............................................................................................................. 72

Conclusion .................................................................................................................................. 72

Chapter 5 Discussion ........................................................................................................... 74

Summary of the study ........................................................................................................... 74

Differences in TCK and TPK between grade levels taught (RQ 1)............ 75

Differences in TCK and TPK between science content area certifications (RQ 2) ............................................................................................................... 76

Teachers describing their own use of TPACK (RQ 3)............................. 77

How science teachers use technology (RQ 4)........................................... 79

Describing how, why, and to what extent secondary science teachers report using technology in their classrooms (RQ 5).................................................... 80

Implications............................................................................................................................. 81

Implications for theory........................................................................................................... 82

Implications for research....................................................................................................... 82

Implications for practice ........................................................................................................ 83

Recommendations for theory, research, and practice ..................................... 84

Recommendations for theory ............................................................................................... 84

Recommendations for research............................................................................................ 85

Recommendations for teacher education ................................................................. 86

Recommendations for practice ........................................................................................... 87

References ............................................................................................................................ 90

Appendix A ............................................................................................................................. 103

Appendix B ............................................................................................................................. 105

Appendix C ............................................................................................................................. 106
List of tables

Table 1 Overview of School Characteristics ................................................................. 27
Table 2 School District Financial Information .............................................................. 28
Table 3 Community Information .................................................................................... 29
Table 4 Overview of Data Collection and Analysis Timeline Plan ................................... 31
Table 5 Technological Content Knowledge (TCK) coding - hardware ............................. 36
Table 6 Technological Content Knowledge (TCK) coding - software ............................. 37
Table 7 Technological Pedagogical Knowledge (TPK) coding ........................................ 38
Table 8: Number of Science Teachers in Participating School Districts .......................... 43
Table 9: Demographic Characteristics of Science Teachers .......................................... 44
Table 10: TPACK Levels of Participating Teachers ......................................................... 46
Table 11: Tests for Normality, Skewness, and Outliers in the TPACK Sum Scores .......... 49
Table 12: Comparison of Mean TPACK Scores by Educational Level and Years of Teaching.. 53
Table 13: Comparison of Mean TPAK Scores by Science Teaching Certifications .......... 55
Table 14: Interview Participants TCK Mentioned and TPK Levels .................................. 65
List of figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>TPACK Model</td>
<td>11</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Map of South-Central School Districts in Pennsylvania</td>
<td>26</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Power Analysis for ANOVA</td>
<td>48</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Frequency Distribution Histogram of TPACK Sum Scores</td>
<td>50</td>
</tr>
<tr>
<td>Figure 5</td>
<td>An Example of a Teacher’s Lesson Using Jamboard for Collaborative Work</td>
<td>62</td>
</tr>
<tr>
<td>Figure 6</td>
<td>An Example of a Zoom Lesson from One of the Participating Teachers</td>
<td>66</td>
</tr>
</tbody>
</table>
Chapter 1

Introduction

Computers – specifically, microcomputers or personal computers - started appearing in schools in the 1980’s and 1990’s, as people began to recognize the advantages of computers in education (Haran, 2015; Beach, 2016). Since that time, computer-based technology has expanded enormously, with new hardware and software appearing consistently (Thompson & Parthasarathy, 2006). Today’s students have access to iPads, computers, smart phones, and the internet, both at school and at home (Pittman & Gaines, 2015). According to Collins and Halverson (2018), “we are going through another revolution, on the same scale as the Industrial Revolution…. The Information Revolution or the Knowledge Revolution, and it is fueled by new media technologies” (p. 4). Additionally, the adult work force has become more computerized, which requires new skill sets that schools must consider in order to fully educate a child (Collins & Halverson, 2018, Pittman & Gaines, 2015, Woodward & Hutchison, 2018). Collins and Halverson state “[p]reparing students to communicate in this emerging world requires not simply traditional reading and writing but communicating using different media” (p. 13). To this end, in 2019, the US government increased technology funding in education to $1.17 billion (International Society for Technology in Education, 2018). Technology was now an inseparable part of the education process in a global society.

While teachers may use devices in their personal lives, “merely knowing how to use technology is not the same as knowing how to teach with it” (Mishra & Koehler, 2006, p. 1033). There is not one correct way to teach with technology, leaving it up to the teacher to determine how and when to use technology within their classrooms (Kolb, 2017; Mishra & Koehler, 2006). As Collins and Halverson say, “[t]he innovative instruction that drives many computer
applications actually makes the teacher’s job more difficult... forcing them to test untried ideas, often with unwilling students” (2018, p. 38). Magana (2017) agrees, stating “changing the routines and procedures to which educators have become accustomed is exceedingly discomforting – particularly if one achieves a level of success with practices that have withstood the test of time” (p. 4). In order to add technology into their classrooms, teachers must completely reconsider their assumptions about teaching and learning (Sandholtz, Ringstaff, & Dwyer, 1997; Magana, 2017, Pittman & Gaines, 2015). According to Kolb (2017), “[t]echnology integration is more complex than simply using a technology tool; pedagogical and instructional strategies around the tool are essential for successful learning outcomes” (p. 10). If teachers did not feel comfortable using technology, the difficulty in implementing technology may lead them to avoid it in their classroom all together (Chai, 2019; Sandholtz, Ringstaff, & Dwyer, 1997; Kolb, 2017; Mishra & Koehler, 2006).

Teachers are often regularly required to attend professional development that involves educational technology, to help close the gap between the promise of technology and the struggle with implementing it in the classroom (Sandholtz, Ringstaff, & Dwyer, 1997; Graham, 2011). However, large-scale professional development sessions can be disadvantageous if they focus on how to use the technology itself, rather than on how teachers can implement technology into their specific disciplines (Graham, 2011, Woodward & Hutchison, 2018). Graham states that “[o]ne of the most frequent criticisms of educational technology is that it is driven more by the imperatives of the technology than by sound pedagogical reasons” (p. 1958). With the rapid expansion of computer-based technology, “[t]eachers will have to do more than simply learn to use currently available tools; they also will have to learn new techniques and skills as current technologies become obsolete” (Mishra & Koehler, 2006, p. 1023). Furthermore, different
teachers use computer-based technology in different ways and trying to force technology into the classroom may go against the teacher’s current practices and values (Ottenbreit-Leftwich et al., 2010, Pittman & Gaines, 2015). As Ottenbreit-Leftwich, Glazewski, Newby, and Ertmer (2010) states, “teachers will not spend precious time, energy, and resources learning about a new technology tool and incorporating it into current pedagogical practices if it is not valued” (p. 1322). This can lead to ineffective professional development that does not help teachers to use educational technology to its full potential (Koh, 2013, Pittman & Gaines, 2015). Koh (2013) emphasizes that “[e]mpirical studies of teachers' classroom practices found that ICT [information and communications technology] has more often been used to support their current instructional practices which focus on information transmission activities” (p. 888). Woodward and Hutchison (2018) agreed, stating that “teachers continually report difficulty with integrating technology and a need for more support in this area” (p. 614). Even with an increase in professional development focused on technology, it was clear from these studies that teachers require more support when it comes to using computer-based technology in education (Koh, 2013; Mishra & Koehler, 2006; Ottenbreit-Leftwich et al., 2010; Sandholtz, Ringstaff, & Dwyer, 1997; Kolb, 2017, Pittman & Gaines, 2015).

**Problem Statement and Significance**

As technology becomes more prevalent in schools and society, it will be essential for both students and teachers to use technology in their learning (Woodward & Hutchison, 2018, Williams, 2017). Existing research demonstrates that there was a need to better support in-service science teachers’ technological content knowledge and technological pedagogical knowledge (i.e., Campbell & Abd-Hamid, 2013; Chai, 2019; Harris, 2016; Pringle, Dawson, & Ritzhaupt, 2015; Williams, 2017). However, professional development that is too broad will not
help teachers to leverage technology in their own content areas (An & Reigeluth, 2012; Williams, 2017).

In order to investigate the problem further, this study examined secondary science teachers’ technological pedagogical content knowledge (TPACK) perspectives and experiences. Specifically, technological pedagogical knowledge (TPK) and technological content knowledge (TCK) were considered in order to determine how, why, and to what degree secondary science teachers use (or did not use) technology within their classrooms. Niess, van Zee, & Gillow-Wiles (2010) indicate that teachers become more student centered as their TPACK level increases. The findings from this study can inform professional development intended to better support the use of technology by in-service secondary science teachers.

**Research Questions**

The following research questions guided this practitioner inquiry project.

RQ 1: Is there a difference in technological content knowledge (TCK) or technological pedagogical knowledge (TPK) between science teachers in grades 7-12?

RQ 2: Is there a difference in technological content knowledge (TCK) or technological pedagogical knowledge (TPK) between science teachers certified in different subject areas (i.e., biology, chemistry, etc.)?

RQ 3: How do secondary science teachers describe their levels of TCK or TPK?

RQ 4: How do secondary science teachers describe and/or explain how they use technology to support their specific content areas?

RQ 5: How does the analysis of both data sets help to describe how, why, and to what extent secondary science teachers report using technology in their classrooms?
These questions allowed me to dissect qualitative and quantitative data separately, and to determine how the two types of data sources offer a greater understanding of how, why, and to what extent secondary science teachers report using (or not using) technology within their classrooms.

Limitations

There were several limitations to this study. First, because the study focused only on grades 7-12 science teachers, the results may not be generalizable to other content areas or grade level teachers. Also, teachers involved in the study may be limited by what technology resources were available at their schools.

The TPACK survey was self-reported, meaning it relies on participants to answer truthfully. There was a chance that the data taken from the survey results may be skewed (Northrup, 1997). This study used a convenience sample, and the qualitative data will only be taken from teachers willing to be interviewed. However, this approach to sampling may be accurate and useful for practitioner research that seeks to address a contextualized problem of practice (Gillham et al, 2019).

This research only focused on teachers; the perspectives of students were not included. The data collected concentrated on teachers’ instructional processes and decisions, and therefore students were not directly relevant to this study. However, future studies may expand on these ideas by including student perspectives.

Delimitations

The study was focused on secondary science teachers in order to spotlight specific needs for future professional development. Only teachers who were Pennsylvania state certified science subject teachers were included (i.e., those who have completed a university program and/or have
a state issued certification to teach a certain subject area). All contributors worked in one of the participating school districts in Lebanon County, Pennsylvania, USA. (Location information was changed in the final dissertation document to protect the identities of all subjects involved. See Chapter 3 for more information on the deidentification process.)

**Definition of Terms**

In this section, I explain the meanings of terms that will be used throughout the study. How technology was specifically used in each classroom was described within my qualitative results.

**Content knowledge (CK)** was “the amount and organization of knowledge per se in the mind of the teacher” (Shulman, 1986, p. 9). It describes the teacher’s knowledge of their discipline, including the truths, misconceptions, syntax, and controversies (Shulman, 1986).

**Educational technology** was “the study and ethical practice of facilitating learning and improving performance by creating, using and managing appropriate technological processes and resources” (Januszewski, & Molenda, 2008, p.1).

**Information and communication technology (ICT)** “a collection of technical devices and resources which are used to transmit, store and manage information” (Hussain et al, 2017, p.77).

A “**large suburb**” was defined by the National Center for Education Statistics (2006b) as a “territory outside a principal city and inside an urbanized area with population of 250,000 or more.”

**Pedagogy** was defined as “the theory and instruction of teaching and learning that comes from the Greek ‘to lead the child’” (Page, 2018).
Secondary school was “A school comprising any span of grades beginning with the next grade following an elementary or middle school (usually 7, 8, or 9) and ending with or below grade 12. Both junior high schools and senior high schools are included” (National Center for Education Statistics, 2018).

A “small city” was defined by the National Center for Education Statistics (2006b) as a “territory inside an urbanized area and inside a principal city with population less than 100,000.”

A “small suburb” was defined by the National Center for Education Statistics (2006b) as a “territory outside a principal city and inside an urbanized area with population less than 100,000.”

Technology will be described as stated by Campbell and Abd-Hamid (2013) as “any digital or electronic tool used in teaching for the purpose of helping students learn science” (p. 573). As this study focuses only on science teachers, this definition will be used for technology.

Technological content knowledge (TCK) was defined as “the knowledge about the manner in which technology and content are reciprocally related” (Mishra & Koehler, 2006, p. 1028). Teachers with a high level of TCK will understand how technology can enhance their content area and student comprehension of their content.

Technological pedagogical knowledge (TPK) was defined as the “knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and conversely, knowing how teaching might change as the result of using particular technologies” (Mishra & Koehler, 2006, p.1028).

Technological Pedagogical Content Knowledge (TPACK or TPCK) was defined by the authors Mishra and Koehler (2006) as
the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students’ prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones (p. 1029).

Conclusion

Technology was an important component in education. However, teachers may not be fully prepared to incorporate technology into their specific content areas. This study aimed to investigate how, why, and to what degree secondary science teachers use (or did not use) technology within their classrooms in order to inform professional development intended to better support the use of technology by in-service secondary science teachers.
Chapter 2

Literature Review

The focus of this chapter was the review of existing literature related to middle and high school teachers’ use of computer-based technology. Technological pedagogical content knowledge (TPACK) was discussed first as a theoretical framework, followed by a more in-depth discussion on technological content knowledge (TCK) and technological pedagogical knowledge (TPK). Next, the integration of educational technology was discussed. Then, science teachers’ technology integration with respect to TPACK was examined. Finally, because this study focused on schools within suburban and small city districts, an analysis of the needs of content and technology-based professional development in smaller schools was included.

Theoretical Framework: TPACK

Shulman’s 1986 article “Those who understand: Knowledge growth in teaching” described a shift in teaching to focus on pedagogy and content. The central question of that article was how expert students become novice teachers, and how learning for teaching occurs (Shulman, 1986). In order to study those concepts, Shulman described different areas of teacher knowledge. Content knowledge was the understanding of the truths and rules for the given discipline (Shulman, 1986). Shulman states “[teachers] must also be able to explain why a particular proposition is deemed warranted, why it is worth knowing, and how it relates to other propositions, both within the discipline and without, both in theory and in practice” (Shulman, 1986, p. 9). Pedagogical knowledge includes knowledge of instructional methods, tools that teachers may use, as well as the ability to relate the discipline to other subjects (Shulman, 1986).

The two concepts together create the Pedagogical Content Knowledge (PCK) model, a combination of both knowing the content and knowing how to teach it (Shulman, 1986). PCK
was a complex mixture of different factors that contribute to the work of a teacher (Shulman, 1986). Schulman argued that the key to effective teaching is bringing together both pedagogical knowledge and content knowledge (Shulman, 1986). Since the publication of Shulman’s article, research has continued to explore how the overlap of pedagogy and content impact teaching and learning (Mishra & Koehler, 2006). At that time, many teacher preparation programs were also redesigned to instruct preservice teachers in developing their PCK (Hofer & Grandgenett, 2012).

One of the extensions of Shulman’s PCK model was the Technological Pedagogical Content Knowledge (TPACK) model, developed by Mishra and Koehler (2006). With the explosion of new technologies available inside and outside of schools, Mishra and Koehler recognized that technological knowledge is also an important domain for teaching (Mishra & Koehler, 2006). The TPACK model, as shown in Figure 1, shows overlapping knowledge areas of pedagogy, content, and technology (Mishra & Koehler, 2006). Each concept can also be defined individually, or as smaller overlapping concepts (Mishra & Koehler, 2006). For instance, Technological Pedagogical Knowledge (TPK) depicts the overlap of technology knowledge and pedagogical knowledge (Mishra & Koehler, 2006).
Since the publication of the original TPACK article, the TPACK framework has been used as a foundation in over 1,000 publications and there have been numerous studies attempting to validate different scales and surveys relating to TPACK and all of its subdomains (Harris et al., 2017). One extension is the TPACK-Deep scale, created by Yurdakul, Odabasi, Kilicer, Coklar, Birinci, & Kurt (2012). In their article, the authors describe the creation, reliability, and validity of the TPACK-Deep scale, which is a 33 question, 5-point Likert scale (Yurdakul et al., 2012).

To begin, a group of 24 faculty members in educational technology from different higher education institutions in Turkey created a list of 146 indicators of TPACK (Yurdakul et al., 2012). From that list of indicators, the authors created a preliminary scale and tested it on 995 pre-service teachers who were students in a variety of educational programs (Yurdakul et al., 2012). Overall, the TPACK-Deep scale was shown to have a high reliability and validity ($\alpha = .95$ for the whole scale, and ranged from .85-.92 for the individual factors), and the scale was able to “significantly discriminated the individuals belonging to the lower and higher groups” (p. 972),
meaning this scale can determine which participants have a higher TPACK level (Yurdakul et al, 2012). The scale was found to have four factors – design, exertion, ethics, and proficiency.

“Design” involves a teacher understanding how technology and pedagogy can enrich teaching content (Yurdakul et al, 2012, p. 969). “Exertion” describes a teacher’s ability to use technology for teaching purposes, and to evaluate the usefulness of technology for education (Yurdakul et al, 2012, p. 969). “Ethics” includes both professional ethics and technology ethics such as privacy (Yurdakul et al, 2012, p. 970). Finally, “proficiency” describes a teacher’s ability to integrate technology, pedagogy, and content; to solve problems that arise related to technology, pedagogy, or content; and choosing the most appropriate solutions (Yurdakul et al, 2012, p. 270). Because of these factors, the TPACK-Deep scale was an appropriate tool to use for this study, where the researcher was aiming to determine TPACK differences between teachers.

The difference between the TPACK-Deep scale and other TPACK scales (i.e., the “TPACK-Science Self Efficacy Scale” by Kiray (2016) or the “Rubric for assessing TPACK for meaningful learning with ICT” by Koh (2013)) is that the TPACK-Deep scale measures the entirety of TPACK, instead of separate domains (Yurdakul et al, 2012). In the authors’ view, “the TPACK-deep scale differs from other TPACK data collection tools and allows measuring and examining TPACK competencies correctly” (Yurdakul et al, 2012, p. 974). This research shows that the TPACK-Deep scale can be a powerful tool to measure teacher’s TPACK levels.

**Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK)**

Within the TPACK framework are the concepts of technological content knowledge (TCK) and technological pedagogical knowledge (TPK) (Mishra & Koehler, 2006). According to Mishra and Koehler (2006), TCK is “knowledge about the manner in which technology and
content are reciprocally related” (p. 1028) and TPK is “knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and conversely, knowing how teaching might change as the result of using particular technologies” (p. 1028). As an example, TPK may be knowing that simulation websites can be effective tools for teaching, whereas TCK may be knowing how simulation websites can help a student to understand science (Mishra & Koehler, 2006). The two concepts are very closely related and can be difficult to separate in real classroom situations (Mishra & Koehler, 2006).

In a meta-analysis of TPACK research focused on elementary and secondary teachers, Hofer and Harris (2012) focused specifically on studies that described in-service teachers’ technological content knowledge (TCK) and technological pedagogical knowledge (TPK). The authors found that TPK took precedence over TCK in nearly every study that was reviewed (Hofer & Harris, 2012). There were several proposed reasons for the prevalence of TPK. First, all of the sections of TPACK are interdependent and therefore challenging to tease out (Hofer & Harris, 2012). Second, experienced teachers may be focused just on pedagogy and technology, as they are already experts in their subject area (Hofer & Harris, 2012). Third, because the domains of TPACK are so connected, an experienced teacher’s TCK and TPK may be one and the same (Hofer & Harris, 2012). Finally, it may be that the current tools used to measure TPACK may not be sensitive enough to truly differentiate between the different subdomains (Hofer & Harris, 2012). The authors suggest that, as more research applies TPACK to specific content areas, it will become easier to apply specific domains within TPACK (Hofer & Harris, 2012).

Teaching with Technology

Initiated in 1985, the Apple Classrooms of Tomorrow (ACOT) project investigated how technology in the classroom would impact teaching and learning (Ringstaff, Yocam, & Marsh,
The results of ACOT were published in a book by Sandholtz, Ringstaff, and Dwyer (1997). While slightly outdated, this research provides insight into how teachers learn to use technology over long periods of time and the results are still used in studies today (such as Pringle, Dawson, and Ritzhaupt, 2015). The authors described five stages of technology integration: entry, adoption, adaptation, appropriation, and invention (Sandholtz, Ringstaff, and Dwyer, 1997). In the entry phase, teachers had little to no computer technology experience, but other technology, such as overhead projectors, was available in some classrooms (Sandholtz, Ringstaff, and Dwyer, 1997, p. 37). In the adoption phase, teachers used some computer technology to supplement traditional practices (Sandholtz, Ringstaff, and Dwyer, 1997, p. 39). In the adaptation phase, about 30-40% of learning took place using a computer, but traditional practices were still paramount (Sandholtz, Ringstaff, and Dwyer, 1997, p. 40). Students began to progress through lessons faster and showed more engagement (Sandholtz, Ringstaff, and Dwyer, 1997, p. 40). In the appropriation phase, a major shift could be noted in teacher behavior (Sandholtz, Ringstaff, and Dwyer, 1997). As the authors noted, “appropriation is the turning point for teachers – the end of efforts simply to computerize their traditional practice” (Sandholtz, Ringstaff, and Dwyer, 1997, p. 43). Finally, in the invention phase, teachers experimented with new technology, students collaborated more often, and teachers spent more time reflecting on their practices (Sandholtz, Ringstaff, and Dwyer, 1997, p. 47).

In a study of 356 school principals and 702 primary and secondary teachers in Spain, Badia, Meneses, Sigales, and Fabregues (2014) examined which factors affect teachers’ perceptions of instructional benefit of technology in the classroom. The authors found that the teachers’ demographics (specifically gender and content area), digital literacy, and frequency of internet use all showed “the strongest correlations with teachers’ perceived effectiveness of
digital technology” (Badia et al, 2014, p. 361). School characteristics were less important (Badia et al, 2014). This study demonstrates that technology use in the classroom was a highly variable practice from teacher to teacher.

Barron, Kemker, Harmes, and Kalaydjian (2003) performed a study of 2,156 Florida teachers, where they measured instructional modes of technology integration as described in the International Society for Technology Education’s (ISTE) National Education Technology Standards for Students (NETS-S). The survey used aligned with the NETS-S in that it measured technology use as a research tool for students, as a problem-solving/decision making tool, as a productivity tool (to make products such as charts), and as a communication tool (Barron et al, 2003). When comparing different grade levels, the authors found that “elementary teachers were twice as likely to use computers as a problem-solving tool or communication tool than high school teachers,” perhaps because elementary teachers have a more flexible schedule than high school teachers (Barron et al, 2003, p. 503). Because this study was older (2003), it was possible that technology use has changed in all grade levels now that teachers have easier access to technology. As for subject areas, the authors found that science teachers and math teachers were more likely to use computers than English or social studies teachers, with science teachers using technology more than any other subject studied (Barron et al, 2003). This study also highlights that different teachers use technology in different ways, and therefore may need to be trained specifically for technology use in their disciplines.

**Science Teachers and TPACK**

According to Harris and colleagues (2017), the future of the TPACK model will lie in its application to teacher practice to focus on “representations of teachers’ knowledge in action, and the reasoning processes that lead to specific technological pedagogical, and curriculum-based
decisions and teaching acts within particular teaching and learning contexts” (p. vi). Graham, Burgoyne, Cantrell, Smith, St Clair, and Harris (2009) agreed, stating that pedagogical use of technology is strongly influenced by the content domain in which it is used. In the past, science was taught with paper, pencil, and basic technology such as hand-held calculators (Niess, van Zee, & Gillow-Wiles, 2010). Yet, science requires ever advancing technology, requiring teachers to integrate technological knowledge in ways that they themselves were never taught (Chai, 2019). For example, biologists need to know how computer programs can analyze molecular structures (Chai, 2019). The TPACK framework can be one method of understanding teacher practices (Harris et al, 2017).

One such study was conducted by Pringle, Dawson, and Ritzhaupt (2015), where the authors examined the lesson plans of science teachers in order to determine the teachers’ technology integration practices. A total of 525 lesson plans were analyzed using specific coding schemes to match the technology integration found in the lesson plans to the TPACK framework (Pringle, Dawson, & Ritzhaupt, 2015). For example, technological content knowledge (TCK) was measured through science-specific software described in the lesson plan (Pringle, Dawson, & Ritzhaupt, 2015). The Pringle, Dawson, and Ritzhaupt study demonstrates a specific qualitative analysis coding scheme that can be used to determine TPACK levels from lesson plan information. Similar coding schemes will be used in this proposed study. More information on coding schemes for this study can be found in Tables 5-7 (page 45-47) in the next chapter.

Niess, van Zee, and Gillow-Wiles (2010) detailed five levels of development when describing a teacher’s integration of technology: recognizing, accepting, adapting, exploring, and advancing. Teachers at different levels held different conceptions of teaching math and science (Niess, van Zee, & Gillow-Wiles, 2010). For example, at the accepting level, teachers used
technology only for fun activities after traditional learning had taken place (Niess, van Zee, & Gillow-Wiles, 2010). However, at the exploring level, teachers valued a more conceptual understanding of topics over procedural learning (Niess, van Zee, & Gillow-Wiles, 2010). In general, as teachers moved toward the “advancing” stage of technology integration, they became more student-centered (Niess, van Zee, & Gillow-Wiles, 2010). Their study supported the importance of focusing on how technology tools can support learning for specific subjects.

In a study of over 500 science teachers in Turkey, Kiray, Celik, and Colakoglu (2018) used a TPACK scale to determine which variables affect science teachers’ TPACK subdomain knowledge. For technological pedagogical knowledge (TPK), the authors found that the subdomains clearly influenced the larger domains. Pedagogical knowledge (PK) and technological knowledge (TK) directly and positively impacted technological pedagogical knowledge (TPK). However, the integration of the two areas were necessary – proficiency in one domain but not the other had no impact on the larger domain. Teachers who had appropriate PK were better able to apply concepts using technology as a tool (Kiray et al, 2018, p. 262). In summary, “a teacher who does not know how to best teach the concepts of science will not be able to integrate technology into the teaching process at an adequate level, no matter how much technology knowledge she has” (Kiray, Celik, and Colakoglu, 2018, p. 262). This article emphasizes the importance of content knowledge and pedagogical knowledge within the TPACK framework. Without CK and PK, the teacher would struggle to use technology all together.

Chai (2019) reviewed 20 different studies on STEM teacher professional development with a focus on technology, pedagogy, and content knowledge used in those professional development sessions. Barriers to STEM teachers using technology include lack of knowledge on new technology, lack of access to the most recent technological advances, and concern about
students’ readiness for advanced topics (Chai, 2019). Chai argues that school STEM classes are often not caught up to modern understandings of STEM (Chai, 2019). Technological content knowledge is “an important mediator of learning by doing and authentic learning since the software embeds the knowledge structures and knowing processes in dealing with data input and output interpretation” (Chai, 2019, p. 10). Chai (2019) contends that more research is needed to determine how TPACK may be used specifically for science learning.

Campbell and Abd-Hamid (2013) created a TPACK-based observational scale specifically for the science classroom. The authors noticed a lack of technology inclusion in science standards, stating that “[w]hile much is outlined in science standards documents about content knowledge and pedagogical knowledge in the U.S., like in many other nations, technological knowledge is scarcely dealt with in these science education standards documents in comparison” (Campbell & Abd-Hamid, 2013, p. 573). The survey that resulted from this study, called “Technology Use in Science Instruction” (TUSI), incorporates technology and science concepts in a way that would measure a teacher’s technological content knowledge through observations of classroom practice (Campbell & Abd-Hamid, 2013). While the TUSI survey does focus on science teachers, its main use is as an observational tool. Because observation is not a part of this proposed research study, the TUSI will not be used as the primary survey tool, but it might be referenced for qualitative coding. The TUSI does show that TPACK research is advancing toward specific instruments for specific content areas.

Guerra, Moreira, and Vieira (2017) created a course designed to teach TPACK to science teachers (both in-service and post-graduate). According to these authors, “science teachers have a crucial role in planning and managing science learning activities with technology” (p. 86); however, “the use of technology in science teaching and learning contexts has remained
irregular” (p. 87). A lack of technology-related training in science education courses can cause science teachers to struggle once they have their own classrooms (Guerra, Moreira, & Vieira, 2017). The authors found that their course did positively impact the use of technology in the participants’ classrooms. For example, one science teacher in the study, who was reluctant to use technology tools, “went on to write her thesis on the topic and continues collaborating with another primary school teacher in a Blog called ‘Pequenos Curiosos’ (Inquisitive Kids)” (Guerra, Moreira, & Vieira, 2017, p. 93). This study underscores the importance of technology training for science teachers, and that some teachers may not have been trained properly in their pre-service education.

Graham, Burgoine, Cantrell, Smith, St Clair, and Harris (2009) studied fifteen in service science teachers who completed the SciencePlus professional development program at Brigham Young University in 2008. SciencePlus focused both on science specific pedagogy and science content knowledge. Teachers were also taught how to use science specific technology, such as digital microscopes and GPS devices (Graham et al, 2009, p. 74). The researchers developed a survey to measure the participants’ TK, TPK, TCK, and TPACK both before and after the SciencePlus program. In their article, the authors describe examples of general activities and content-specific activities and how they coded each for the different domains of TPACK. For example, “student use of PPT to create presentations” was coded as TPK, while “use of digital microscopes to extend students ability to observe phenomenon” was coded as TCK (Graham et al, 2009, p 77). These general coding schemes can be useful for future researchers who are analyzing content specific TPACK areas.

Taken together, these studies demonstrated that technology was current and relevant to the teaching and learning of science. However, some science teachers may not have been trained
appropriately (Guerra, Moreira, & Vieira, 2017; Campbell & Abd-Hamid, 2013), and others may lack understanding of specific science-related technologies (Chai, 2019). This study aimed to learn more about the needs of science teachers in terms of their technological professional development.

**The Needs of Small School Districts**

As the school districts participating in this study were all small or medium sized, it was important to consider the specific factors that impact smaller schools. The definition of “small” or “medium” varies widely throughout the existing literature. For the purpose of this study, schools will be ranked based on their size compared to all the other districts in the state of Pennsylvania. According to the Pennsylvania Department of Education (2019c), there were 783 total school districts in Pennsylvania, 500 of which were public schools. The participating school districts rank from 65th largest to 352nd largest schools (Pennsylvania Department of Education, 2019c).

As for rural or urban classification of these districts, all the schools were in communities with a population of less than 10,000 people, with one district being in a community of 25,000+ people. (See Table 3, page 38 for more information about each community.) The National Center for Education Statistics (NCES, 2006a) defines these areas as small cities, large suburbs, or small suburbs (see chapter 1 for definitions). Additional information can be found in Chapter 3.

Lee, Smerdon, Alfeld-Liro, and Brown (2000) studied nine different high schools of varying sizes in order to determine how enrollment size affects curriculum and social interactions. Smaller schools were limited in what services they could offer to their students, because state and local governments decide school funding based on the number of students enrolled in that district, and smaller enrollment often means less funding (Lee et al, 2000). These
results impacted the study because school funding can determine how schools provide technology for their classrooms.

Bertelsten (2018) agrees, stating that “small, rural districts typically can’t offer a “full plate” of electives, have a hard time hiring and retaining teachers and have higher transportation costs per student to bring them longer distances.” Less funding can also mean that school districts must decide where to use their money, which can mean some important educational opportunities were missed (Vincent, 2018). Sometimes, small schools cannot afford to have the latest technological infrastructure, hindering any attempt to use computer-based technology in the classroom (Vincent, 2018). Teachers were limited by which technology the school purchases (Sandholtz, Ringstaff, and Dwyer, 1997; Chai, 2019; Lee et al, 2000), and that could impact the results of this research. For these reasons, this study was examining four small and medium-sized school districts in order to assess their needs for content-specific technology training. School size and school type may impact how, why, and to what degree science teachers use technology in their classrooms, and more research was needed to determine the full impact of these factors in authentic classroom environments.

**Summary**

The literature review presented in this chapter focuses on several key topics. First, the TPACK model, which was used as the framework for this study, was described in terms of its original publication and several supporting publications. Second, teaching with technology was explained through several articles which all observed that teachers use technology in different ways for different subject areas. Third, as this study focused on science teachers’ use of technology, six articles explaining how science teachers use technology were detailed, while also linking these studies back to the TPACK framework. Fourth, because the school districts being
considered were all small or medium sized districts, articles referring to the needs of small or medium sized districts were reviewed, which offer important considerations in this study. These four areas – TPACK, teaching with technology, science teachers’ use of technology, and the needs of small districts – were essential for the study and were explained in Chapter Three.
Chapter 3

Research Design and Methods

This study used a mixed methods research design (Creswell & Plano Clark, 2007) to examine how, why, and to what extent do secondary science teachers report using technology in their classrooms. Mixed methods research “involves both collecting and analyzing quantitative and qualitative data” (Creswell & Plano Clark, 2007, p. 6). This mixing of data “provides a better understanding of the problem than if either dataset had been used alone” (Creswell & Plano Clark, 2007, p. 7). Specifically, an explanatory-sequential mixed methods design was used. Quantitative data was collected first, followed by qualitative data, and finally the two data sets were analyzed together in relation to the research questions. Each part of this design was explained in the sections below.

Explanatory-Sequential Mixed Methods Design

An explanatory design is a form of mixed methods research in which the qualitative data is used to explain the quantitative results (Creswell & Plano Clark, 2007). Explanatory-sequential, which can also be called “follow-up explanations”, starts with quantitative data collection and analysis, followed by qualitative data collection and analysis, with the goal of finding deeper meaning from comparing quantitative and qualitative results (Creswell & Plano Clark, 2007).

The explanatory-sequential design was chosen for this study because it was important to go beyond the answers that teachers provide in a survey. The quantitative data was critical to gather initial data useful for measuring TPK and TCK but understanding why teachers answered the survey in certain ways was also valuable. By analyzing the explanation behind teachers’
answers, issues and solutions to technology integration in secondary science classrooms will be uncovered.

**Research Questions**

As stated in Chapter 1, the following research questions guided this study. The research questions were aligned with each part of the study detailed below.

- **RQ 1:** Is there a difference in technological content knowledge (TCK) or technological pedagogical knowledge (TPK) between science teachers in grades 7-12?
- **RQ 2:** Is there a difference in technological content knowledge (TCK) or technological pedagogical knowledge (TPK) between science teachers certified in different subject areas (i.e., biology, chemistry, etc.)?
- **RQ 3:** How do secondary science teachers describe their levels of TCK or TPK?
- **RQ 4:** How do secondary science teachers describe and/or explain how they use technology to support their specific content areas?
- **RQ 5:** How does the analysis of both data sets help to describe how, why, and to what extent secondary science teachers report using technology in their classrooms?

**Theoretical Framework**

The technological pedagogical content knowledge (TPACK) framework developed by Mishra and Koehler (2006) was the research framework for this study. While the goal of this study was to describe how, why, and to what extent secondary science teachers report using technology in their classrooms, it was very difficult to separate technology use from any other domain of teaching. Content, pedagogy, and technology exist together in the modern classroom (Mishra & Koehler, 2006). The TPACK framework treats pedagogy, content, and technology as overlapping areas of knowledge that are all important to education (Mishra & Koehler, 2006).
Specifically, the technological content knowledge (TCK) and technological pedagogical knowledge (TPK) portions of the TPACK model were used to determine teachers’ level of technology content knowledge and technology pedagogy knowledge within their classrooms.

**Research Context**

The mixed methods study took place in 4 public school districts in south-central Pennsylvania. A map marking all school districts in this region can be seen in Figure 2 (page 36).

Pennsylvania had 500 public school districts, with the largest number (126 districts) occurring in the south-central region of the state (Pennsylvania Department of Education, 2019a). This area includes 14 counties and spans over 200 miles east to west and over 90 miles north to south (Pennsylvania Department of Education, 2019a). The school districts that were participating in this study were located within the same county in this region.

According to the Pennsylvania Department of Education (2019c), the 4 districts participating in this study were small to medium size districts, containing 1,400 to 5,300 students in grades preK-12. Tables 1 and 2 (page 37) summarize the school and community characteristics for the participating school districts. The purpose of studying these specific districts was to collect data on small and medium school districts that can be used to inform professional development for their specific needs. Furthermore, to date there had not been any research studies involving these specific districts. Additional demographic information on individual teachers were collected with the quantitative data.
Figure 2

Map of South-Central School Districts in Pennsylvania

Note: This map was taken from Pennsylvania Department of Education “Pennsylvania education directory maps” (2019a).

Research Sample

The maximum participant numbers were 53 individuals (see Table 1, page 37). The sample size necessary for a 95% confidence level (5% margin of error) was 47 individuals (Claremont Graduate University, 2015). For the interview process, the researcher asked for volunteers and then two respondents from each school district were contacted by the researcher, for eight total interviews. Interview participants came from the pool of survey respondents. Collecting interview information from every survey participant was difficult because of time constraints. The intent of the interviews was to provide more detail to explain the survey results, and therefore a smaller sample of interviews, including participants from every school district, was used for this study (Creswell & Plano Clark, 2007). All of the teachers in these districts had experience with online teaching because of Covid-19 lockdowns.
The following information was available online from the Pennsylvania Department of Education (2019). The total number of K-12 classroom teachers in each district ranges from 101 to 308 individuals, with approximately 70% being female and 30% being male (Pennsylvania Department of Education, 2019). On average, teachers have been in the district for 11 to 13 years and have an education level of a bachelor’s degree or higher (Pennsylvania Department of Education, 2019).

Table 1

Overview of School Characteristics

<table>
<thead>
<tr>
<th>School district (pseudonym)</th>
<th>Total student population (K-12)</th>
<th>Secondary (7-12) student population</th>
<th>Total number of teachers (K-12)</th>
<th>Number of secondary science teachers (7-12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystal River</td>
<td>1451</td>
<td>698</td>
<td>101</td>
<td>18</td>
</tr>
<tr>
<td>River Valley</td>
<td>5267</td>
<td>2108</td>
<td>284</td>
<td>12</td>
</tr>
<tr>
<td>Stonewall</td>
<td>2185</td>
<td>1054</td>
<td>197</td>
<td>12</td>
</tr>
<tr>
<td>Westwood</td>
<td>3618</td>
<td>1755</td>
<td>224</td>
<td>23</td>
</tr>
</tbody>
</table>

Note: Data for this table was taken from the 2018-2019 school district enrollment reports and professional staff summary reports available on the Pennsylvania Department of Education’s website (2019b and 2019c).

The financial data in Table 2 was taken from the Pennsylvania Department of Education’s website. Because financial reporting for school districts was up to two years behind, the most recent data was from the 2017-2018 school year.
Table 2

School District Financial Information

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystal River</td>
<td>$15,278,648.09</td>
<td>$10,915.30</td>
<td>$14,565,564.30</td>
</tr>
<tr>
<td>River Valley</td>
<td>$40,455,391.00</td>
<td>$8,464.11</td>
<td>$18,859,272.95</td>
</tr>
<tr>
<td>Stonewall</td>
<td>$27,874,694.52</td>
<td>$11,486.79</td>
<td>$37,226,592.97</td>
</tr>
<tr>
<td>Westwood</td>
<td>$30,532,784.97</td>
<td>$8,913.45</td>
<td>$33,924,225.87</td>
</tr>
</tbody>
</table>

Note: Data for Table 2 was taken from the Pennsylvania Department of Education’s AFR data website (2019d). The Pennsylvania Department of Education uses the term “tuition rates” to mean the cost of educating a child for one school year.

The community information in Table 3 was available from the United States Census Bureau (2018) and the National Center for Education Statistics (2006a). All four school districts were within the same county, but each community had different characteristics. NCES defines poverty based on information from the US census. The Census Bureau measures poverty based on “a set of money income thresholds that vary by family size and composition” (United States Census Bureau, 2016). If a family’s total income was less than the threshold, that family was in poverty. For example, a four-person family with two children had a threshold of $25,962 (United States Census Bureau, 2016).
Table 3

Community Information

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystal River</td>
<td>8,068</td>
<td>$78,926</td>
<td>1.2%</td>
<td>Small suburb</td>
</tr>
<tr>
<td>River Valley</td>
<td>25,477</td>
<td>$39,371</td>
<td>24.9%</td>
<td>Small city</td>
</tr>
<tr>
<td>Stonewall</td>
<td>11,429</td>
<td>$63,459</td>
<td>6.1%</td>
<td>Small suburb</td>
</tr>
<tr>
<td>Westwood</td>
<td>7,320</td>
<td>$50,437</td>
<td>13.3%</td>
<td>Large suburb</td>
</tr>
</tbody>
</table>

Tables 1-3 highlight important information about the five school districts involved in the study. While all the districts were fairly close geographically, they vary in terms of population, finances, and classification.

Instruments

There were two instruments that were utilized in this study. The TPACK-Deep survey was used for quantitative data. For qualitative data, participants were interviewed individually. Both the TPACK-Deep survey and the interview protocols were detailed below.

Quantitative instruments.

The TPACK-Deep survey developed by Yurdakul, Odabasi, Kilicer, Coklar, Birinci, and Kurt (2012) was used as the survey instrument for this study. It is a 33 question, 5-point Likert scale assessing a teacher’s self-reported use of technology in the classroom. This survey was used to obtain the quantitative data for the proposed study. The TPACK-Deep survey can be found in Appendix A. Permission had been obtained from the authors and can be seen in Appendix B.

The TPACK-Deep survey was chosen because it specifically describes technology integration into classrooms (Yurdakul et al, 2012). In addition, it measures the subsections of TPACK (technology knowledge, pedagogical knowledge, and content knowledge) as
simultaneous overlapping concepts, as they exist in classrooms (Yurdakul et al, 2012). While the original survey was developed using pre-service teachers, the authors state that “[t]his scale could also be used for the evaluation of professional development studies on educational technology integration with respect to teacher TPACK knowledge” (Yurdakul et al, 2012, p. 974). Additionally, the TPACK-Deep survey was found to have a Cronbach alpha of 0.95, with individual factors having a Cronbach alpha of 0.85 and 0.92 (Yurdakul et al, 2012). This makes the TPACK-Deep survey an appropriate tool for measuring TCK and TPK in currently practicing teachers.

**Qualitative instruments.**

For the qualitative component of the study, an interview protocol was used. Interview questions were modeled from Standish (2012) and Campbell & Abd-Hamid (2013). These two sources were appropriate sources for interview protocols because both involve questions for current teachers about their use of instructional technology. The interview protocols can be found in Appendix C. In addition, lesson plans were analyzed to find instances of technology use within each lesson. The lesson plans were intended to be used as a part of the conversation during the interview in order to dig deeper into the respondents’ interview answers about their teaching practices using technology. Both data sets (the interview transcript and the lesson plans) were analyzed in a similar fashion; more information on qualitative analysis can be found in Tables 5-7 (page 45-47).

**Data Collection Process**

Data was collected in two phases over a period of three months. First, quantitative data was collected via the TPACK-Deep survey, sent to teachers via Qualtrics. Qualtrics is a software tool that allows for the creation and analysis of surveys (Qualtrics, 2019). The TPACK-Deep
scale was recreated using Qualtrics, and then the link was sent to the survey participants. Second, qualitative data were taken from teacher interviews and lesson plan analysis. Each portion of the data collection plan was detailed in the following sections, and the data collection timeline can be found in Table 4 (page 40). Classroom observations were not a part of data collection for this study, but observations may be a useful extension of this study in the future. During all phases of data collection, teachers were asked to respond according to their typical classroom environment, and to disregard any new or different uses of technology that may have changed in their classroom as a result of the school shutdowns and virtual learning that took place because of Covid-19.

**Table 4**

*Overview of Data Collection and Analysis Timeline Plan*

<table>
<thead>
<tr>
<th>Data type</th>
<th>Data collection timeline</th>
<th>Data analysis timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantitative (TPACK survey)</td>
<td>November 2020-January 2021</td>
<td>January 2021-April 2021</td>
</tr>
<tr>
<td>Qualitative (Interview/Lesson plan analysis)</td>
<td>April-June 2021</td>
<td>September-November 2021</td>
</tr>
</tbody>
</table>

**Quantitative data collection.**

Given the explanatory-sequential mixed methods design, quantitative data was collected first. A virtual form of the TPACK-Deep survey was created using Qualtrics. All potential subjects were sent an email with the TPACK-Deep survey instrument link. Potential participant emails were gathered from each district or schools’ administration. Participants were given a two-month time span to complete the survey. Periodic email reminders were sent. Teachers who participated had the option to be entered for a prize ($50 Amazon gift card) by filling out a separate Qualtrics form, which was provided at the end of the TPACK survey. (Note that the
prize entry form was a different Qualtrics form that was not linked in any way to their survey responses.) All participating teachers were asked to provide their emails so that they could be contacted for the qualitative portion of the study. Providing an email address was optional, and a short summary of the qualitative data collection process was included so that the respondents understood what they were volunteering for. To prevent multiple responses from the same participant, reminder emails were not sent to teachers who have already provided their email address at the end of the survey. Participant’s quantitative data was separate from their prize entry form and their qualitative data. Data was deidentified by separating the email addresses and survey responses; this was completed by an assistant so that the survey answers were anonymous to the researcher. The deidentification process happened after the survey was closed to new responses.

**Qualitative data collection.**

From the quantitative sample, a smaller sample was contacted to collect additional data through interviews. Participants were selected from survey respondents who volunteer to be interviewed. The goal was for 8-10 teachers to be interviewed (ideally, two from each district). All information was deidentified in the final paper.

Teachers were asked to bring a lesson plan or other lesson materials to the interview. The interview process occurred in two steps. First, the teachers discussed their perspectives and experiences with technology in their subject area. Second, the researcher asked the teachers to share a lesson plan or other materials that demonstrated technology integration in their classrooms. Evidence of technology use in their lessons or lesson plans was discussed. The lesson plan was used as a conversation piece in order to more deeply discuss the teacher’s use of technology, and therefore it was included along with the rest of the interview data. Any
identifying information from the lesson plan (i.e., names, school names, etc.) was removed. The total time for the interview was about 20-30 minutes. Specific times were decided according to the participant’s and the researcher’s schedules. The researcher requested to retain a copy of the lesson plan for further qualitative analysis after the interview had concluded. The interview responses were recorded and transcribed. The lesson plans were added to the qualitative data analysis (see “data analysis process”). An interview protocol can be found in Appendix C.

Mixed methods data collection.

The survey responses, the interview transcripts, and the collected lesson plans were compared in order to describe if the results of the survey (quantitative data) support the interview responses and lesson plan analysis (qualitative data). The quantitative data and qualitative data were separate data sets; teachers who respond to the survey was not directly connected to their interview/lesson plan answers. The goal was for the information from both data sets to be compared as a group, not individually. The majority of the mixed methods data was only available after both the quantitative and qualitative data sets have been compared.

Data Analysis Process

Because this was an explanatory-sequential mixed methods design, the quantitative survey data was analyzed first, followed by the qualitative data. Mixed methods analysis occurred throughout the study. Each portion of the proposed analysis was detailed below.

Quantitative analysis.

Quantitative data was derived from the responses provided from the TPACK-Deep survey (Yurdakul et al, 2012). See Appendix A for the survey. The TPACK-Deep survey results were intended to answer research question one and two.
According to the creators of the TPACK-Deep scale, the sum of each individual’s responses indicates that individual’s level of TPACK (Yurdakul et al., 2012). Scores below 95 were considered low TPACK, scores between 96 and 130 were considered medium TPACK, and scores above 131 were considered high TPACK (Yurdakul et al., 2012). Therefore, for each survey respondent, the sum score was obtained by coding the answers on a scale from one to five. One represented “strongly disagree,” two represented “disagree,” three represented “neither agree or disagree,” four represented “agree”, and five represented “strongly agree.” In addition, the mean, standard deviation, and range for the TPACK scores were included.

SPSS Descriptive Statistics was used to determine if there were statistically significant differences between the groups. The groups were defined as 1) total years of experience teaching their certified subject (teachers input a number), 2) the different science certifications (i.e., biology, chemistry, physics, etc.), and 3) the different grade levels taught (7-12). The independent variables were the different groups, and the dependent variable was the score on the TPACK-Deep survey. An ANOVA test was used to compare the TPACK sum score to each group. More information can be found in Chapter 4.

**Qualitative analysis.**

From those who respond to the quantitative survey, a smaller qualitative sample was formed. Teachers that responded to the survey were asked to provide their email addresses if they would like to volunteer for the interviews. This was a convenience sample, where individuals who responded were used for the study (Creswell & Plano Clark, 2007). Initially, only three teachers volunteered. Because a sample representing all disciplines and grade levels would produce the most complete data set, all potential participants were emailed again to ask for interview volunteers. A total of six interviews were completed. It was possible for a teacher
to count as two data points. For example, a 10th grade biology teacher could count within both the “10th grade teachers” group and the “biology teachers” group. The qualitative data was used to answer research questions three and four.

Data collection happened over the course of one interview with teachers, where we discussed their TPACK and evidence of TPK and TCK in their lessons. Teachers were asked to bring a lesson plan to the interview. The interview protocols can be found in Appendix C. Most interviews took place over Zoom, except for two that were completed in person. Copies of the lesson plan were retained in order to further analyze them for qualitative information. The lesson plan was intended to be a conversation piece in order to further investigate the teacher’s use of technology, and therefore the lesson plan was combined with the participants’ interview responses.

Using the Pringle, Dawson, and Ritzhaupt (2015) article as a guide, teachers’ lesson plans and interview answers were examined in order to determine the level of TPK and TCK in their instructional practices. TCK was described by the types of hardware and software present in the teachers’ lesson plans, or from the technology that each teacher described through the interview (see Tables 5 and 6, page 45-46). TPK was described by the levels of technology integration as cited in Pringle, Dawson, and Ritzhaupt (2015). (See Table 7, page 47). Measuring teachers’ TPACK levels through use of technology was cited frequently in the literature, such as in Maeng, Mulvey, Smetana, and Bell (2013) and Pringle, Dawson, and Ritzhaupt (2015).
Table 5

*Technological Content Knowledge (TCK) coding - hardware*

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Potential code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell phone</td>
<td>Cell phone</td>
</tr>
<tr>
<td>Computer (including laptop)</td>
<td>Computer</td>
</tr>
<tr>
<td>Data collection hardware (probes, microscopes, etc.)</td>
<td>Data collection</td>
</tr>
<tr>
<td>Document camera</td>
<td>Camera</td>
</tr>
<tr>
<td>Graphing calculator or networked calculator</td>
<td>Calculator</td>
</tr>
<tr>
<td>Interactive whiteboard/SMART board/Promethean board</td>
<td>Whiteboard</td>
</tr>
<tr>
<td>Tablet (iPad, Kindle, Nook)</td>
<td>Tablet</td>
</tr>
<tr>
<td>Other</td>
<td>Other</td>
</tr>
</tbody>
</table>

Note: adapted from Pringle, Dawson, and Ritzhaupt (2015) and Graham, Burgoyne, Cantrell, Smith, St Clair, and Harris (2009)
Table 6

*Technological Content Knowledge (TCK) coding - software*

<table>
<thead>
<tr>
<th>Software</th>
<th>Example</th>
<th>Potential code</th>
</tr>
</thead>
<tbody>
<tr>
<td>App-based content-specific resources</td>
<td>Anatomy 4D, NOVA Elements</td>
<td>Apps</td>
</tr>
<tr>
<td>Content-specific games</td>
<td>Bitesize Games, EcoDefenders</td>
<td>Games</td>
</tr>
<tr>
<td>Online datasets</td>
<td>US census, CDC statistics</td>
<td>Dataset</td>
</tr>
<tr>
<td>Online textbooks</td>
<td>Provided via publishers, or free online (i.e., CK-12, Open Stax)</td>
<td>Textbook</td>
</tr>
<tr>
<td>Video learning software</td>
<td>YouTube, Kahn Academy</td>
<td>Online learning</td>
</tr>
<tr>
<td>Virtual fieldtrips</td>
<td>Zoo cameras, museum online tours</td>
<td>Fieldtrip</td>
</tr>
<tr>
<td>Virtual simulations</td>
<td>PhET</td>
<td>Simulation</td>
</tr>
<tr>
<td>Web-based content-specific resources</td>
<td>Science Kids, BrainPop</td>
<td>Web</td>
</tr>
<tr>
<td>Other</td>
<td>To be determined</td>
<td>Other</td>
</tr>
</tbody>
</table>

Note: adapted from Pringle, Dawson, and Ritzhaupt (2015) and Graham, Burgoyne, Cantrell, Smith, St Clair, and Harris (2009)
### Table 7

*Technological Pedagogical Knowledge (TPK) coding*

<table>
<thead>
<tr>
<th>Code</th>
<th>Example artifact contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry</td>
<td>• Little or no use of computer-based technology</td>
</tr>
<tr>
<td></td>
<td>• Noted struggle with classroom management or discipline with</td>
</tr>
<tr>
<td></td>
<td>technology in the classroom</td>
</tr>
<tr>
<td></td>
<td>• Replicate traditional activities</td>
</tr>
<tr>
<td>Adoption</td>
<td>• Technology supports existing instruction (same strategies)</td>
</tr>
<tr>
<td></td>
<td>• Find ways to adapt technology to established curriculum or</td>
</tr>
<tr>
<td></td>
<td>pedagogy</td>
</tr>
<tr>
<td>Adaptation</td>
<td>• Thorough* use of technology in the classroom</td>
</tr>
<tr>
<td></td>
<td>• Traditional practices (lecture, seat work, etc.) remain the</td>
</tr>
<tr>
<td></td>
<td>focus</td>
</tr>
<tr>
<td></td>
<td>• Increased teacher and student productivity</td>
</tr>
<tr>
<td>Appropriation</td>
<td>• Effortless* use of technology in the classroom</td>
</tr>
<tr>
<td></td>
<td>• New habits; change of beliefs about technology</td>
</tr>
<tr>
<td>Invention</td>
<td>• More focus* on problem-based instruction</td>
</tr>
<tr>
<td></td>
<td>• Individually paced instruction</td>
</tr>
<tr>
<td></td>
<td>• Use technology to experiment with new instructional ideas</td>
</tr>
</tbody>
</table>

Note: adapted from Sandholtz, J.H., Ringstaff, C., and Dwyer, D.C. (1997) and Pringle, Dawson, and Ritzhaupt (2015). According to Sandholtz, J.H., Ringstaff, C., and Dwyer, D.C. (1997), the starred words above were described as follows:

- “Thorough” – students used technology for approximately 30-40% of the school day (p. 40).
- “Effortless” – the teacher comes to understand technology as a tool to accomplish real work (p. 43).
- “More focus” – the teacher can experiment with new instructional ideas (p. 44).
All interviews were audio recorded and later transcribed into a Word document. Because of the small number of interviews, the researcher coded each one by hand. See Tables 5, 6, and 7 (page 45-47) for coding information.

Preliminary transcribing and coding began as soon as the first interviews and lesson plans were collected and was an ongoing process. The preliminary coding was line-by-line, according to the information found in Tables 5-7 (pages 45-47). Any other codes were saved for possible future research.

Pringle, Dawson, and Ritzhaupt (2015) rationalize their choice of codes that can be seen in Tables 5-7 through several cited references. TPK levels of integration was supported by Sanholtz et al. (1997). TCK as described by specific content-related software used in lessons was supported by Kersaint (2003). This study followed similar coding schemes. Additional coding schemes were adapted from Graham, Burgoyne, Cantrell, Smith, St Clair, and Harris (2009) who studied in service science teachers and coded their responses to a TPACK survey. Proposed coding schemes can be found in Tables 5-7 (pages 45-47).

**Mixed methods analysis.**

The quantitative portion (the TPACK survey) occurred first, followed by the qualitative interview. The mixed methods analysis occurred throughout the study as information was received. In general, the researcher was looking for connections and trends between the survey results, the interviews, and the lesson plans. The mixed methods analysis was intended to answer research question five.

**Ethical Considerations**

All participants were recruited from the districts that agreed to participate in the study. Email addresses were collected from the districts’ administrators (superintendent, principals,
Teachers were emailed with the online survey link; participation was voluntary. Teachers filled out an online consent agreement before starting the survey. Those who volunteer for the qualitative study were emailed separately to set up an interview time.

Potential participants received a consent form before beginning the online survey. If the participant did not agree to consent, then they were redirected out of the survey instrument website. Assent was not required as minors were not a part of this study.

Participants learned about the conditions of their participation from the consent form. They received an email from the researcher containing the consent form and survey instrument. This email also contained the contact information for the researcher, the PI, and the IRB director in case they should have had any questions or concerns before, during, or after their participation. Also, within both the email and the consent form was information on how to withdraw from the study. Participants may withdraw at any point, and their information will be deleted (including names and contact information). Participation was voluntary and choosing not to participate did not affect their teaching position; school administration was not told which teachers did or did not participate. Participants were informed that their survey data will be retained after deidentification in order to use the other parts of the TPACK-Deep survey for a potential follow up study. Recruitment email scripts can be found in Appendix D. There were consent forms for both the survey and the interview process.

Schools and teachers participating in this study were identified using pseudonyms (see Table 1, page 37). All identifying information was secured. Survey information was deidentified before being included in the final study. Within the study, participants were asked to provide their email addresses in order to 1) contact them for the qualitative data interview, and 2) to prevent asking the same person to fill out the survey twice. Those who volunteered to be
interviewed were contacted first, followed by more targeted recruitment to produce an accurate sample size. Participant’s quantitative data were not connected to their prize entry form or their qualitative data. (The survey responses and interview responses/lesson plans were two different data sets.) Participants were informed that their survey data will be retained after deidentification in order to use the other parts of the TPACK-Deep survey for a potential follow up study. The final study was shared with the superintendents and principals of the participating schools. Because school and district information were given pseudonyms, the administration did not directly know which participant was from which school. Administration members may choose to share the results with members of the school board, the school staff, or the surrounding communities.

Data will be kept for a period of five years. After this point, all data will be destroyed. Physical data (papers) will be shredded, and digital data will be encrypted and then deleted from the computer.

Conclusion

In summary, this mixed methods study occurred in two phases. First, a TPACK survey was sent to participants and second, volunteers from the group were interviewed and have a lesson plan analyzed. Quantitative data was analyzed using SPSS statistics software. Qualitative data was analyzed using coding techniques adapted from the available literature. More information on the results can be found in the next chapter.
Chapter 4
Results

This chapter contains the results of the mixed methods study that was conducted to answer the following research questions. First, is there a difference in technological content knowledge (TCK) or technological pedagogical knowledge (TPK) between science teachers in grades 7-12? Second, is there a difference in technological content knowledge (TCK) or technological pedagogical knowledge (TPK) between science teachers certified in different subject areas (i.e., biology, chemistry, etc.)? Third, how do secondary science teachers describe their levels of TCK or TPK? Fourth, how do secondary science teachers describe and/or explain how they use technology to support their specific content areas? Fifth, how does the analysis of both data sets help to describe how, why, and to what extent secondary science teachers report using technology in their classrooms? The results will be separated into quantitative, qualitative, and mixed methods results.

This study used an explanatory-sequential mixed methods design (Creswell & Plano Clark, 2007) to examine how, why, and to what extent did secondary science teachers report using technology in their classrooms. An explanatory design is a form of mixed methods research in which the qualitative data is used to explain the quantitative results (Creswell & Plano Clark, 2007). Explanatory-sequential starts with quantitative data collection and analysis, followed by qualitative data collection and analysis, with the goal of finding deeper meaning from comparing quantitative and qualitative results (Creswell & Plano Clark, 2007). The explanatory-sequential design was chosen for this study because it was important to go beyond the answers that teachers provided in a survey. The quantitative data was critical to gather initial data useful for measuring TPK and TCK but understanding why teachers answered the survey
was also valuable. By analyzing the explanation of teachers’ answers, issues, and solutions to technology integration in secondary science classrooms can be uncovered.

**Quantitative results**

While there were six school districts in the sampling area, only four agreed to participate and were approved through IRB. The numbers of teachers who were listed as science teachers in grades 7 to 12 in each school district were summarized in Table 8. (This information was taken from the school’s website or from communication from the school’s superintendent.) Each district was located in the same county in south-central Pennsylvania. Each was considered a small or medium sized district, although they all vary in characteristics such as population and poverty level. Additional information on these districts can be found in Chapter 3. In many school districts, “middle school” includes 6 through 8, and “high school” includes grades 9 through 12. However, some of the districts in this study did not have a separate middle and high school (i.e., they have one “secondary” school encompassing all of those grades), so the data in Table 8 was not separated into middle versus high school to protect the anonymity of the participants.

**Table 8**

*Number of Science Teachers in Participating School Districts*

<table>
<thead>
<tr>
<th>School district (pseudonym)</th>
<th>Total number of secondary science teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystal River</td>
<td>6</td>
</tr>
<tr>
<td>River Valley</td>
<td>19</td>
</tr>
<tr>
<td>Stonewall</td>
<td>9</td>
</tr>
<tr>
<td>Westwood</td>
<td>19</td>
</tr>
</tbody>
</table>
Quantitative results

Data was obtained through the TPACK-Deep survey developed by Yurdakul, Odabasi, Kilicer, Coklar, Birinci, and Kurt (2012). The survey was added to Qualtrics and then sent to participants via emails collected from their district superintendents. Research questions one and two were answered from the quantitative data.

A total of 22 teachers completed the survey, representing 41.5% of the 53 science teachers in the four participating school districts. Because the teachers were not randomly sampled from the population, the survey data collected from the volunteer sample were not necessarily representative of the entire population of teachers. Table 9 outlines the demographic information that the 22 science teachers reported as part of the survey.

Table 9

Demographic Characteristics of Science Teachers

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Category</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science teaching certifications from the State of</td>
<td>No science certifications</td>
<td>9</td>
<td>40.9%</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>Biology 7-12</td>
<td>5</td>
<td>22.7%</td>
</tr>
<tr>
<td></td>
<td>Chemistry 7-12</td>
<td>2</td>
<td>9.1%</td>
</tr>
<tr>
<td></td>
<td>Earth and Space Science 7-12</td>
<td>2</td>
<td>4.5%</td>
</tr>
<tr>
<td></td>
<td>Environmental science K-12 and Biology 7-12</td>
<td>1</td>
<td>4.5%</td>
</tr>
<tr>
<td></td>
<td>Middle level 6-8, Chemistry 7-12, and General</td>
<td>1</td>
<td>4.5%</td>
</tr>
<tr>
<td></td>
<td>Science 7-12</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle level 6-8</td>
<td>1</td>
<td>4.5%</td>
</tr>
<tr>
<td></td>
<td>Biology 7-12, Chemistry 7-12, and General</td>
<td>1</td>
<td>9.1%</td>
</tr>
<tr>
<td></td>
<td>science 7-12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>School where they were currently teaching</td>
<td>High (Grade 9, 10, 11, and 12)</td>
<td>11</td>
<td>50.0%</td>
</tr>
<tr>
<td></td>
<td>Middle and High (Grades 7, 8, 9, 10, 11 and 12)</td>
<td>4</td>
<td>18.2%</td>
</tr>
<tr>
<td></td>
<td>Middle (Grade 7 and 8)</td>
<td>2</td>
<td>9.1%</td>
</tr>
<tr>
<td></td>
<td>Do not currently teach in grades 7 through 12</td>
<td>5</td>
<td>22.7%</td>
</tr>
<tr>
<td>Years of teaching science subjects</td>
<td>Shorter time (0-14 years)</td>
<td>12</td>
<td>55%</td>
</tr>
<tr>
<td></td>
<td>Longer time (15-35 years)</td>
<td>10</td>
<td>45%</td>
</tr>
</tbody>
</table>
Thirteen (59.1%) of the twenty-two teachers had science certifications from the Commonwealth of Pennsylvania, while nine (40.9%) did not have any science certifications. Ten teachers (45%) reported that they were certified in only one subject area, and three (14%) reported being certified in more than one subject area. The subjects they were certified in included biology, chemistry, environmental science, earth and space science, middle level science, and general science. The researcher did not verify the teachers’ subject areas – what the participants stated on the survey was what was reported here. Eleven participants (50%) were teaching in a high school only (grades 9-12). Four teachers (18.2%) were teaching in both a middle school and a high school. Two (9.1%) were teaching in a middle school only (grades 7-8). Five teachers (22.7%) reported that they did not teach in grades seven through twelve (i.e., they teach in another grade level). Their years spent teaching science subjects in grades 7-12 ranged from zero (they were in their first year of teaching at the time of the survey) to thirty-five years. Over half of the teachers (54.5%) had between eight and sixteen years of experience, while only two teachers (9.1%) had taught for 25 or more years.

TPACK levels.

According to the creators of the TPACK-Deep scale, the sum of each individual’s responses indicates that individual’s level of TPACK (Yurdakul et al, 2012). Scores below 95 were considered low TPACK, scores between 96 and 130 were considered medium TPACK, and scores above 131 were considered high TPACK (Yurdakul et al, 2012). There were no missing values, therefore the scores were not biased by some teachers not responding to one or more of the survey items.

For each survey respondent, the sum score was obtained by coding the answers on a scale from one to five. One represented “strongly disagree,” two represented “disagree,” three
represented “neither agree or disagree”, four represented “agree”, and five represented “strongly agree.” The sum of each individual’s scores can be found in the table below. Among the twenty-two teachers, the majority (twelve, or 54.5%) were classified as high TPACK, while nine (30.9%) were classified as medium TPACK, and only one (4.5%) was classified as low TPACK (sum score = 86).

Table 10

TPACK Levels of Participating Teachers

<table>
<thead>
<tr>
<th>Response number</th>
<th>Sum score</th>
<th>TPACK score meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>135.00</td>
<td>high</td>
</tr>
<tr>
<td>2</td>
<td>163.00</td>
<td>high</td>
</tr>
<tr>
<td>3</td>
<td>86.00</td>
<td>low</td>
</tr>
<tr>
<td>4</td>
<td>129.00</td>
<td>medium</td>
</tr>
<tr>
<td>5</td>
<td>126.00</td>
<td>medium</td>
</tr>
<tr>
<td>6</td>
<td>157.00</td>
<td>high</td>
</tr>
<tr>
<td>7</td>
<td>115.00</td>
<td>medium</td>
</tr>
<tr>
<td>8</td>
<td>119.00</td>
<td>medium</td>
</tr>
<tr>
<td>9</td>
<td>149.00</td>
<td>high</td>
</tr>
<tr>
<td>10</td>
<td>157.00</td>
<td>high</td>
</tr>
<tr>
<td>11</td>
<td>145.00</td>
<td>high</td>
</tr>
<tr>
<td>12</td>
<td>126.00</td>
<td>medium</td>
</tr>
<tr>
<td>13</td>
<td>127.00</td>
<td>medium</td>
</tr>
<tr>
<td>14</td>
<td>143.00</td>
<td>high</td>
</tr>
<tr>
<td>15</td>
<td>132.00</td>
<td>high</td>
</tr>
<tr>
<td>16</td>
<td>144.00</td>
<td>high</td>
</tr>
<tr>
<td>17</td>
<td>115.00</td>
<td>medium</td>
</tr>
<tr>
<td>18</td>
<td>126.00</td>
<td>medium</td>
</tr>
<tr>
<td>19</td>
<td>156.00</td>
<td>high</td>
</tr>
<tr>
<td>20</td>
<td>147.00</td>
<td>high</td>
</tr>
<tr>
<td>21</td>
<td>138.00</td>
<td>high</td>
</tr>
<tr>
<td>22</td>
<td>121.00</td>
<td>medium</td>
</tr>
</tbody>
</table>

Descriptive statistics for the sum scores found a mean score of 134.36, with a standard deviation of 17.97. The lowest score was 86, and the highest was 163. Overall, most of the responding teachers indicated a medium or high level of TPACK.
Testing the Assumptions of ANOVA

The purpose of an ANOVA test was to test the null hypothesis that no statistically significant differences existed between the groups of teachers (Field, 2018). The TPACK sum score was the dependent variable, and the groups of teachers classified by their demographic characteristics (grade level taught, certifications, and years of experience) were the independent variables. Before using ANOVA, the assumptions of ANOVA were tested as follows.

First, the total sample size and the number of participants within each ANOVA group must be large enough to provide adequate statistical power to detect significant differences within the dependent variable (Kang, 2021). To provide maximum statistical power, the sampling design must be balanced (Rutherford, 2011). If the sample size was too small, the sampling design was imbalanced, then ANOVA was underpowered, and a Type II error will occur (i.e., the results were declared not significant, even though the test would be significant if the sample size was larger). Figure 3 presents the results of a power analysis to determine if the observed sample size of twenty-two teachers was large enough to detect statistically significant differences in mean TPACK scores, assuming a balanced sampling design.
The input parameters were a moderate effect size ($f = .25$), a conventional level of statistical significance ($\alpha \text{ err prob} = 0.05$), an adequate level of power ($1 - \beta = 0.8$), and three fixed categories of teachers (classified by certification level, school level, or years of experience). The required total sample size estimated to conduct ANOVA was one hundred and fifty-nine total teachers (i.e., fifty-three teachers in each of three groups). The required sample size to conduct ANOVA was over six times greater than the observed sample size. Even when the effect size was increased to large ($f = 0.50$), the required sample size was forty-two, which was still greater than the observed sample size. The conclusion was that ANOVA was underpowered, and that Type II errors were expected.

Second, the dependent variable in ANOVA must be reliably measured, and approximately normally distributed (Field, 2018; Laerd Statistics, 2018). Table 11 presents the results of tests for internal consistency reliability (Cronbach’s alpha), normality (Shapiro-Wilk statistics and skewness), and outliers (Z-scores) among the TPACK sum scores. The internal consistency reliability of the scores was very good (Cronbach’s alpha = .951) and the scores did
not deviate significantly from normality (p = .344). The skewness statistic (-.643) was within the expected normal limits (± 1.0). Figure 4 (page 59) illustrates the approximately bell-shaped frequency distribution of the TPACK sum scores. The minimum and maximum Z-scores (-2.69 to 1.59) were within the expected normal limits (± 2.3) reflecting no outliers, therefore parametric statistics were appropriate to summarize the scores.

Table 11

Tests for Normality, Skewness, and Outliers in the TPACK Sum Scores

<table>
<thead>
<tr>
<th>Test</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal consistency reliability</td>
<td>Cronbach’s alpha (33 items) = .951</td>
</tr>
<tr>
<td>Shapiro-Wilk Test for Normality</td>
<td>Test statistic = .952, p = .344</td>
</tr>
<tr>
<td>Skewness statistic</td>
<td>-0.643</td>
</tr>
<tr>
<td>Minimum Z-score</td>
<td>-2.69</td>
</tr>
<tr>
<td>Maximum Z-score</td>
<td>1.59</td>
</tr>
</tbody>
</table>
The mean TPACK sum score was 134.40 and the variability in the scores either side of the mean score was reflected by the standard deviation of 17.97. The median or central value of 133.50 was close to the mean, reflecting the symmetry of the frequency distribution. Eleven (50%) of the participants scored below the mean, and eleven (50%) scored above the mean.

Third, the dependent variable in ANOVA must be measured at the interval level (Field, 2018; Laerd Statistics, 2018). Several reviews on the analysis of Likert scales have concluded that the summation of questionnaire items with 5-point response formats creates scales measured at the interval level, which can be analyzed using parametric statistics, including ANOVA (Carifio & Perla, 2008; Sullivan & Artino, 2013; Wu & Leung, 2017).

The fourth assumption of ANOVA was homogeneity of variance. Levene’s test was available in SPSS to check for homogeneity of variance (Field, 2018); however, the results of
this test were unreliable if the sample size in each group was too small (< 30) and if the group sizes were unequal (Kim & Cribbie, 2017; Levy & Keyes, 1997; McGuiness, 2002; Parra-Frutos, 2013). Therefore, it was not possible to accurately test for homogeneity of variance using this sample of teachers.

The final assumption was that, in order to determine if the ANOVA F-test statistic was statistically significant at the conventional .05 level, the raw data must be collected by random sampling. However, the teachers who participated in the current study were volunteers and were not selected by random sampling.

The conclusion based on the testing of assumptions was that the p values of the ANOVA F-test statistics were not appropriate to provide the statistical evidence to address the research questions. The elimination of p values did not imply that the research questions could not be addressed because many alternative methods were available to interpret the results of quantitative research in education, including effect sizes (Balow, 2017; Lipsey et al., 2012; Kraft, 2019; Scheerens, 2017) and confidence intervals (Young & Young, 2021; Zientec et al., 2012; Young et al., 2013). Those alternative methods were described below.

Standardized measures of effect size (e.g., Cohen’s d, Hedge’s g) were not appropriate to compare the mean TPACK sum scores (Kraft, 2019) because this study did not follow a true experimental design. Confidence intervals (CI) were appropriate because they have been demonstrated to accurately estimate the difference between two or more values in various education research (Cumming, 2008; Cumming & Calin-Jageman, 2017; Cumming & Fidler, 2009; Fethey, 2010; Fidler & Loftus, 2009; Hoekstra et al., 2012; Lai & Kelley, 2012; Pandis, 2013). For example, Young, J., Young, J., & Hamilton, C. (2013) used confidence intervals to summarize the effects of teacher education technology courses on preservice teacher TPACK.
Another study by Young, J., Young, J., Hamilton, C., & Smitherman Pratt, S. (2019) evaluated the effects of professional development on urban mathematics teachers TPACK using confidence intervals. Therefore, it was appropriate to use 95% confidence intervals to address the research questions.

**Confidence Intervals**

The mean values of the TPACK scores extracted from the sample data were biased by measurement error and were only point estimates of the true mean values in the population from which the sample was drawn (Kock, 2015). It was therefore necessary to compute the confidence intervals of the mean TPACK score. To facilitate the calculation and interpretation of 95% confidence intervals, it was necessary to collapse large number of demographic categories of teachers into fewer categories, so that the sample size in each category was increased, and each category was approximately equal in size (see Table 9, page 53).

**Research Question One**

Table 11 (page 57) provides the evidence to address question one by summarizing the mean TPACK sum scores ± 95% CI classified by two demographic characteristics, each of which contained two approximately equal categories: (1) by the current grade level assignment of the teachers and (2) by the years of experience, classified by a shorter time (0 to 14 years) vs. a longer time (15 to 35 years). The respondents were grouped in this way in order to collapse the data into fewer categories to correctly calculate the confidence intervals.
Table 12
Comparison of Mean TPACK Scores by Grade Level Taught and Years of Teaching

<table>
<thead>
<tr>
<th>Demographic characteristic</th>
<th>Categories</th>
<th>Sample size</th>
<th>Mean TPACK score</th>
<th>95% CI of Mean score</th>
<th>Mean difference</th>
<th>95% CI of Mean difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td>Lower</td>
</tr>
<tr>
<td>Grade level currently taught *</td>
<td>High school only</td>
<td>11</td>
<td>136.73</td>
<td>121.75</td>
<td>150.71</td>
<td>4.73</td>
</tr>
<tr>
<td></td>
<td>Other levels</td>
<td>11</td>
<td>132.00</td>
<td>123.27</td>
<td>140.73</td>
<td>-</td>
</tr>
<tr>
<td>Years of teaching science subjects</td>
<td>0 to 14</td>
<td>12</td>
<td>137.00</td>
<td>123.90</td>
<td>150.09</td>
<td>5.50</td>
</tr>
<tr>
<td></td>
<td>15 to 35</td>
<td>10</td>
<td>131.20</td>
<td>120.74</td>
<td>141.66</td>
<td>-</td>
</tr>
</tbody>
</table>

Note. “High school only” were teachers who only work in grades 9-12. “Other levels” includes teachers working in grades 7-8, plus any teachers who work in both school levels.

The mean TPACK sum scores for all categories of teachers were greater than 131, reflecting that, in at least 95% of the samples, the teachers could be classified as high TPACK. (According to the authors of the TPACK-Deep survey, a mean score of 131 or higher reflects a high level of TPACK.) The lower limits of the 95% CI below 131 mainly represented those teachers who were classified as medium TPACK. The mean sum score of 136.73 for the high school only teachers was greater than that for the other teachers (132.00). The mean sum score of 137.00 for teachers who had taught science for a shorter time was greater than that for the teachers who had taught science for a longer time (131.20).

The 95% CI of both groups overlapped, which indicates that the higher CI scoring groups did not necessarily demonstrate a higher TPACK than the other groups. The lower limits of the 95% CI of the point estimates of the mean differences were negative, and the upper limits were positive, such that the confidence intervals captured zero (equivalent to p > .05).
However, these results also did not imply that no differences existed between the technical knowledge of each group. While the statistical analysis showed no differences between the TPACK scores, this does not apply to every individual teacher within each group. The positive values of the CI indicated that in 95% of the samples, the mean difference between the TPACK of approximately half of the teachers in each group, was greater than the point estimate. The negative values of the CI indicated that, in 95% of the samples, the mean differences between the TPACK of approximately half of the teachers in each group was less than the point estimate. In summary, it can be concluded that there was some difference between each group. With the small sample size, the researcher cannot conclude if the differences were significant.

Research question one was intended to answer if there was there a difference in technological content knowledge (TCK) or technological pedagogical knowledge (TPK) between science teachers in grades 7-12. Because of the sample size, it was not possible to measure the TPACK of teachers in each individual grade level. For the science teachers that were studied, there was some difference, according to their CI data. Overall, it was not possible to state if there was a difference between teachers in each grade level, in part, because every grade level was not represented in the data. Research question one was not able to be conclusively answered with this data.

**Research Question Two**

The sample sizes within each group of teaching areas (e.g., biology, chemistry, environmental science, general science) were too small to compare using ANOVA or 95% CI. Therefore, statistics were run for teachers with science certifications and without science certifications. Table 13 summarizes the CI data both from the group of teachers who reported
that they did have science certifications and from the group of teachers who reported that they
did not have any of the science certifications listed.

Table 13

Comparison of Mean TPACK Scores by Number of Science Teaching Certifications

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Category</th>
<th>Sample size</th>
<th>Mean TPACK score</th>
<th>95% CI of Mean score</th>
<th>Mean difference</th>
<th>95% CI of Mean difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science teaching</td>
<td>No science certifications</td>
<td>9</td>
<td>139.33</td>
<td>129.15</td>
<td>-8.41</td>
<td>-24.60</td>
</tr>
<tr>
<td>certifications</td>
<td></td>
<td></td>
<td></td>
<td>Upper</td>
<td></td>
<td>7.78</td>
</tr>
<tr>
<td></td>
<td>With science</td>
<td>13</td>
<td>130.92</td>
<td>118.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>certifications</td>
<td></td>
<td></td>
<td></td>
<td>Upper</td>
<td>143.26</td>
<td></td>
</tr>
</tbody>
</table>

The mean TPACK sum scores for all categories of teachers classified by certifications
were greater than 131, reflecting that, in at least 95% CI of the samples, the teachers could be
classified as high TPACK. (According to the authors of the TPACK-Deep survey, a mean score
of 131 or higher reflects a high level of TPACK.) The lower limits of the 95% CI below 131
mainly represented those teachers who were classified as medium TPACK.

As stated above (page 60) in the discussion for research question one, the point estimates
did not imply that the TPACK knowledge of the “no science certifications” group was greater
than those who reported specific certifications. The positive confidence limits indicated that the
TPACK of approximately half of the teachers with no science certifications was greater than that
of the teachers with science certifications. In summary, it can be concluded that there was some
difference between the two groups.

Research question two asked if there was a difference in technological content knowledge
(TCK) or technological pedagogical knowledge (TPK) between science teachers certified in
different subject areas (i.e., biology, chemistry, etc.). However, not all science certification areas
were represented in the data, and some certification areas were not represented at all. The teachers who were studied did have some differences, according to their CI data. However, it was not possible to apply those results to science teachers in every certification area. For that reason, research question two was not able to be fully answered.

**Summary of quantitative results**

TPACK sum scores demonstrated that most of the participating teachers demonstrated a high or medium level of TPACK (Table 10, page 55). While ANOVA was initially considered as the statistical test for this study, the collected data did not follow the assumptions of ANOVA. Therefore, confidence intervals were used instead. Confidence intervals (CI) were appropriate because they have been demonstrated to accurately estimate the difference between two or more values in other educational research articles (Cumming, 2008; Cumming & Calin-Jageman, 2017; Cumming & Fidler, 2009; Fethey, 2010; Fidler & Loftus, 2009; Hoekstra et al., 2012; Lai & Kelley, 2012; Pandis, 2013), including several TPACK studies by Young et al. (Young, Young, & Hamilton, 2013; Young, Young, Hamilton, & Smitherman Pratt, 2019).

To answer research question one, teachers were grouped into teaching only in a high school vs. teaching in any other setting (i.e., grades 7-8, or grades 7-12) and teaching a shorter time (0-14 years) vs. a longer time (15-35 years). This grouping was necessary to calculate the confidence interval tests given the overall small sample size of participants. As explained above (page 60), regrouping in this way allowed for the sample sizes to be approximately equal. Using groups that were too small could result in higher error. Confidence intervals determined that at least 95% of the sample of teachers can be classified as having a high TPACK (Table 12, page 61). Also, confidence intervals showed that there was some difference between the groups based
on the number of years teaching (Table 12, page 61). See the section above (page 60) on research question one for more explanation.

To answer research question two, teachers who reported having no science certification were compared to teachers who reported having one or more specific certifications. Again, this grouping was necessary to calculate the confidence interval tests given the overall small sample size of participants. Confidence intervals determined that there was some difference between the groups (Table 13, page 63).

In summary, the answers for research question one (Is there a difference in TCK or TPK between science teachers in grades 7-12?) and research question two (Is there a difference in TCK or TPK between science teachers certified in different subject areas?) were inconclusive. As shown in Tables 12 and 13 (pages 61-63), confidence intervals demonstrated that there was some difference between each group (grade levels and certifications), but it was not possible to verify if the difference was significant because of the sample size. These results also cannot be applied to every science teacher within the population. All grade levels and certifications were not represented within the sample data. Also, grade levels and certifications had to be collapsed into larger groups for calculating confidence intervals, so it was not possible to determine differences between individual grades or certifications. It was not possible to conclusively answer these two research questions with the data from this study.

**Qualitative results**

Data was collected via interviews with six different teachers who volunteered to be interviewed for this study. These teachers also responded to the survey. Due to Covid-19 IRB protocols, interviews were conducted through and recorded using Zoom. Interviewed teachers
also shared a lesson plan or similar materials through email. Interview protocols can be found in Appendix C. Research questions three and four were answered from the qualitative data.

Each interview was transcribed and coded using methods described in Chapter 3. The Pringle, Dawson, and Ritzhaupt (2015) article was used as a guide for coding TPK and TCK. Additional coding schemes were adapted from Graham, Burgoyne, Cantrell, Smith, St Clair, and Harris (2009). Coding information can be found in Tables 5-7 (pages 45-47). Other codes came from dissecting the question responses.

First, demographic information will be discussed. Second, each qualitative theme will be described. The qualitative analysis demonstrated five overall themes – (a) needs for future professional development, (b) resource choice and needs, (c) importance of technology in the real world, (d) importance of technology in science instruction, and (e) the dynamic nature between technological content knowledge (TCK) and technological pedagogical knowledge (TPK). All teacher and school names were pseudonyms. Some course names have been altered to protect the anonymity of the participants. Images of lessons or lesson plan materials were included to demonstrate the teachers’ use of technology.

**Demographic information.**

The six teachers who were interviewed represented three of the four districts in this study. No teachers from the Westwood School District volunteered to be interviewed. Of the interviewed teachers, two were teaching science in a middle school, and four were teaching science in a high school. Four teachers taught life science classes (i.e., biology) and two taught physical science classes (i.e., chemistry, physics). These teachers all have Pennsylvania certification for their subject areas (they were not among the “no certification” group found
within the quantitative data). Overall, they have eight to thirty-six years of experience teaching their subject areas.

**Describing past professional development.**

Concerning past professional development, none of these teachers had training in technology use specifically for science education. They did have training for general technology use that addresses the whole teaching staff, especially with the virtual learning that occurred as a result of Covid-19. Angel from Crystal River School said “it was more generalized on how to use it” to describe district technology training. Three teachers noted that their peers were their best source of learning. Avery from Stonewall School said “We have a couple of people who are very sharp when it comes to technology. They run short classes, different things… I’ll tell you what, I’m so glad they stepped up to do that.” Four teachers described training through outside sources independent of their district. Some teachers noted training that occurred through their local universities, or through vendors who were selling scientific devices. The teachers who attended those events chose to improve their own professional learning and were not guided by their districts in what to learn.

**Needs for future professional development.**

In terms of future learning, all the teachers said that they were open to more professional learning opportunities. Jamie from River Valley School stated, “I don’t even know what’s out there as to like, what could be the best fit for what I am doing in classes that I could use for digital and online learning.” They want to know more, especially about new technologies that might benefit students. For specific technology tools, teachers noted that games, simulations, and other virtual learning technologies would be most beneficial to them. All of the teachers expressed a need to incorporate technology meaningfully and purposefully. Sam from River
Valley School said “I think there could be a lot done for schoolwide PD in regard to how we use these things meaningfully. Because they’re there and not a lot of people know how to access them.” Taken as a whole, these teachers want to learn more and seem open to the idea of adding more technology in the future.

**Resource choice and needs.**

When deciding which resources to use, teachers noted ease of use, resource availability, and peer recommendations. Avery from Stonewall School stated, “First of all, I have to be able to use it.” Max from Stonewall School said that any resource needs to be “a time saver, not a time sucker.” Both Sam and Devin (from River Valley School) noted that technology must be meaningful to the students. Devin said “I like the students to be able to either gain something from it or put something into it. Not just using it for the sake of saying that they did it.” Having resources already available was helpful as well. Max gives the following example. “For EdPuzzle, I can put my own videos in and put my own questions or I can search and see if somebody else has done the same video. And I can always edit their questions if I don’t like it.” Several teachers agreed that peer recommendations help them to choose their resources. Both Jamie from River Valley and Angel from Crystal River noted specific staff who helped them to make the best of virtual learning during Covid-19. The quotes that include their coworkers’ names have been omitted to protect their anonymity.

As for resource needs, several of these teachers discussed the need for technology training specifically targeted to their subject areas. Avery from Stonewall said, “I think it would be nice for some new ideas of what you could use specifically for science.” Angel from Crystal River agreed, saying that “…a lot of things I’ve learned this year have been from teacher TikTok. I wish I would have somebody at my district who would be willing to share and kind of
do more professional development specific to science instead of just everyone in general.”

Teachers noted a lack of games, virtual labs, and other science tools that would make virtual science learning better. Sam from River Valley explained “What we have right now, it just takes so many steps in order to prepare. That could be more streamlined, it could be easier.” The teachers were open and willing to learn more about technology for science education, but they were also looking for guidance from their schools and peers.

**Importance of technology in the real world.**

All the interviewed teachers agreed that technology was important in science education. Four of the teachers mentioned that technology was essential for students to develop skills they will need in their adult lives. Max from Stonewall School noted that “[students] are not going to go to get a job where they’re answering questions out of a textbook. So, they’re going to be able to need to maneuver different types of technology.” Two other teachers remarked how technology was integral to modern life, and that students need to know how to use it effectively.

Three of the teachers discussed how technology was essential to science in the real world. Sam from River Valley stated “with regard to science… so much of our communication is asynchronous across time and space, and we’re constantly reviewing articles and research that was written in other countries in years prior. I like to do as much as I can to get my students to communicate and collaborate similarly.” Others agreed that communication and collaboration were key for science in the real world. Figure 5 below (page 71) shows an example of how a teacher used Jamboard as a collaborative tool. Jamboard is an online program where multiple people can work on one document simultaneously, mirroring the idea of in person collaboration. In this way, students can discuss and work together in real time even if they were separated by physical distance. In Jamboard, the teacher can add some tiles (for example, the title
“Armadillo”) and then students can work together to add in the other tiles according to their assignment directions. In this figure, the students had to list characteristics of armadillos that proves they were living things.

**Figure 5**

*An Example of a Teacher’s Lesson Using Jamboard for Collaborative Work*

Two teachers described that they feel they need to keep up with the times. Angel from Crystal River explained:

“We are living in a tech world, where it is advancing faster than what we realize, and especially in science…. Keeping up with technology is just opening the doors for new technology to come about. I think incorporating that into your course is just preparing your students that want to take that next step in life.”

Max from Stonewall agrees, stating that “we can’t hide from technology.” In sum, these teachers recognize the importance of technology. The work of these teachers was supported by the International Society for Technology in Education (ISTE) standards, including student standard 1.6 “Creative Communicator: Students communicate clearly and express themselves creatively for a variety of purposes using the platforms, tools, styles, formats and digital media appropriate to their goals” and 1.7 “Global Collaborator: Students use digital tools to broaden
their perspectives and enrich their learning by collaborating with others and working effectively in teams locally and globally” (International Society for Technology in Education, 2022). In addition, their work was supported by the Pennsylvania state “Reading and Writing in Science and Technical Subjects” standards, which contains standard CC.3.6.11-12.E: “use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information” (Commonwealth of Pennsylvania, 2022).

**Importance of technology in science instruction.**

In their classrooms, two teachers explained how technology enhances their instruction. As Jaime from River Valley said, “What I’ve noticed is that the more resources that I give the students… the easier they understand with less effort…. They can use [videos] in case they don’t understand, and they can rewatch it. That’s something you can’t do with lecturing.” Angel from Crystal River School agreed that teachers should be embracing technology more. “I think what technology does is it allows us to almost like differentiate for learners a little bit easier…. Technology is kind of like the great equalizer because it allows all the kids to learn.” Several other teachers also agreed that technology increases their ability to differentiate to the students’ needs.

**Dynamic nature between technological content knowledge (TCK) and technological pedagogical knowledge (TPK).**

As stated in Chapter 3, measuring teachers’ TPACK levels through use of technology was cited frequently in the literature, such as in Maeng, Mulvey, Smetana, and Bell (2013) and Pringle, Dawson, and Ritzhaupt (2015). Also, TCK and TPK were considered together because it can be difficult for teachers to differentiate between the two in their classrooms (Hofer & Harris,
2012; Yurdakul et al, 2012). The information in this section answers research question three, how do secondary science teachers describe their levels of TCK or TPK? Note that this qualitative theme had “dynamic nature” added because TCK and TPK were different for every teacher, but also linked together in most classrooms. There was not one correct way to show TCK or TPK.

Teachers’ lesson plans and interview answers were examined in order to determine the level of TPK and TCK in their instructional practices. TCK was described by the types of hardware and software present in the teachers’ lesson plans, or from the technology that each teacher describes through the interview. TPK was described by the levels of technology integration as cited in Pringle, Dawson, and Ritzhaupt (2015). See Tables 5-7 (pages 45-47) for more information on coding methods.

Each interview participant was matched with their level of TPK in Table 14, as described by Sandholtz, J.H., Ringstaff, C., and Dwyer, D.C. (1997) and Pringle, Dawson, and Ritzhaupt (2015).
### Table 14

*Interview Participants TCK Mentioned and TPK Levels*

<table>
<thead>
<tr>
<th>Participant (School)</th>
<th>TCK mentioned - hardware</th>
<th>TCK mentioned - software</th>
<th>TPK level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avery (Stonewall)</td>
<td>Cameras, scientific probes</td>
<td>Zoom, Jamboard, Kahoot, Schoology, online videos, games</td>
<td>Between adoption and adaptation</td>
</tr>
<tr>
<td>Sam (River Valley)</td>
<td>iPads</td>
<td>Google platform, Zoom, Schoology, Nearpod, Actively Learn</td>
<td>Invention</td>
</tr>
<tr>
<td>Max (Stonewall)</td>
<td>iPads, Chromebooks</td>
<td>Simulations, EdPuzzle, online videos, Quizizz, Schoology</td>
<td>Between adaptation and appropriation</td>
</tr>
<tr>
<td>Jamie (River Valley)</td>
<td>MacBook, Smartboard</td>
<td>Schoology, EdPuzzle, Nearpod, QuickTime</td>
<td>Between adoption and adaptation</td>
</tr>
<tr>
<td>Devin (River Valley)</td>
<td>Microscopes, gel electrophoresis, iPads</td>
<td>Google platform, Schoology</td>
<td>Invention</td>
</tr>
<tr>
<td>Angel (Crystal River)</td>
<td>Chromebooks</td>
<td>Zoom, virtual labs, Google platform, Jamboard</td>
<td>Between appropriation and invention</td>
</tr>
</tbody>
</table>

For technological content knowledge (TCK), the use of technology within teachers’ lessons was measured based on which technologies were mentioned in the interview and lesson plan materials. Technology was separated based on hardware or software. It appears that all of these teachers have access to computers or tablets (or both), although some teachers mentioned that they would prefer a different device. Max from Stonewall School notes “I would like to have a class set of iPads. The students have Chromebook. But there are certain things that I can manipulate better on an iPad.” Only two of the six teachers mentioned technology that is specific to science education (such as microscopes).

The software and websites used represent a wide range of platforms and a creative use of available resources. Some tools were for collaboration (such as Jamboard and Zoom), some tools were for presentations (such as EdPuzzle, Nearpod, and QuickTime), and some tools were for
gamification of learning (such as Quizizz or Kahoot). Those websites were not specifically for science education, but these teachers adapted those tools for use in their classrooms. Shown in Figure 6 was an example of an interviewed teacher who used Zoom to teach their online students, and an example of Jamboard can be found in Figure 5 (page 70). Science specific software was mentioned in the form of virtual labs and simulations, which were provided by many institutions such as the University of Colorado’s PhET simulations.

**Figure 6**
An Example of a Zoom Lesson from One of the Participating Teachers

A description of how the teachers’ technological pedagogical knowledge levels were determined was described in Chapter 3. Table 14 (page 73) shows the TPK levels of each participant. Two teachers reached the highest level of “invention” because they demonstrated a focus on problem-based, individualized instruction, and they were clearly experimenting with new ideas. The other four teachers seemed to be in between steps; however, none of them were
at the lowest level of “entry.” All showed some level of technology incorporation and adaptation in their lessons. See Table 7 (page 47) for more information on how the levels were described.

However, lesson plans may not always reflect what actually happens in the classroom. To further support the TPK level of each teacher, quotes taken from their interviews will be presented below.

Avery from Stonewall described a TPK level in between adoption and adaptation. “Adoption” includes technology supporting existing instruction and finding ways to adjust technology to fit the established curriculum (see Table 7, page 47). “Adaptation” includes keeping traditional practices as the focus and thorough use of technology in the classroom (see Table 7, page 47). Avery mentioned students working with peers at home via Zoom. “They would have the camera on and they would be doing the experiment so that the kids can see it that are at home. They can answer the questions together.” Also, Avery mentioned “I would put [the students] in groups with big whiteboards…. They would be given a problem… and would have to do things like show the equation, show your work…. With Jamboard, we can put it up on [their screens], and they can explain what they did. So, the Jamboard is actually replacing the whiteboards.” (Note that one of the subjects that Avery teaches was physics, which does include equations.) In these examples, Avery shows that technology tools were substituted for in person learning tools in order to facilitate collaboration while students were physically separated. These characteristics match with the adoption and adaptation levels of TPK. Avery exhibited the “adoption” level because the students were doing the same lesson as they would in a regular classroom. Avery demonstrated the “adaptation” level because students were still completing the assignment in the same manner, only with Jamboard replacing traditional whiteboards.
Sam from River Valley demonstrated a TPK level of invention. “Invention” focuses on problem-based instruction, individually paced instruction, and using technology to experiment with new ideas (see Table 7, page 47). In the interview, Sam described a lesson that “incorporated the Google Platform via Google Forms, and MURAL as a collaborative workspace for the [students] to use.” (Note that Google Suite is now called Google Workspace.) In this lesson, students had to use prior knowledge and technology tools in order to complete a collaborative project about cells and organelles. In doing so, Sam had to try new tools. “The MURAL program, that was something I found out of the blue to replace physical manipulatives that I would have had otherwise in the classroom.... I explored different options, different programs that were out there.” Sam’s willingness to experiment with new technologies in order to try out instruction in a new way, as well as allowing student groups to pace themselves while they work on a problem, shows that Sam had reached the TPK level of invention.

Max from Stonewall demonstrated a level of TPK between adaptation and appropriation. “Adaptation” includes keeping traditional practices as the focus and thorough use of technology in the classroom (see Table 7, page 47). As described in Table 7, “thorough” means “students used technology for approximately 30-40% of the school day” (Sandholtz, Ringstaff, and Dwyer, 1997, p. 40). “Appropriation” involves effortless use of technology in the classroom and new habits or changes of belief about technology (see Table 7, page 47). Max described a lesson where students went through “a series of different steps and websites… in order to review the topic and solidify their knowledge.” In these steps, Max mentioned technology including videos and informative websites. Finally, students played a game and took a screenshot of their final results. Max created different series so that student’s tasks could be differentiated for their needs. (Max did not specify how exactly the lessons were differentiated, only that different students
were directed to unique resources based on their individual needs.) The process was meant to mimic what would happen in the physical classroom. Max described how the same lesson would be set up around the classroom and how students would physically show the teacher their results. Because Max’s lesson explained effortless use of technology but kept traditional practices, Max was placed in between adaptation and appropriation.

Jamie from River Valley demonstrated a TPK level between adoption and adaptation. “Adoption” includes technology supporting existing instruction and finding ways to adjust technology to fit the established curriculum (see Table 7, page 47). “Adaptation” includes keeping traditional practices as the focus and thorough use of technology in the classroom (see Table 7, page 47). Jamie explained a lesson where “I’ve been doing screen casting… and the Smartboard… [to capture] the screen and be able to write and do all of the problems.” Jamie learned about screen casting from coworkers who suggested ways to show traditional lectures through technology. Because Jamie used technology to support traditional practices, Jamie was placed between adoption and adaptation.

Devin from River Valley described a TPK level of invention. “Invention” focuses on problem-based instruction, individually paced instruction, and using technology to experiment with new ideas (see Table 7, page 47). Devin illustrated a virtual escape room using Google Platform tools. “It allowed me to embed my direct lesson so that it was student paced, so that the students had more control… over how they were moving through the modules, but they could also hear directly from me when they needed to.” Devin clearly demonstrated using technologies to create innovative new lesson ideas, which places Devin firmly in the invention level of TPK.

Angel from Crystal River demonstrated a TPK level between appropriation and invention. “Appropriation” involves effortless use of technology in the classroom and new habits
or changes of belief about technology (see Table 7, page 47). “Invention” focuses on problem-based instruction, individually paced instruction, and using technology to experiment with new ideas (see Table 7, page 47). Angel noted “What I’ve done is… a Google Slides… two truths and a lie for the cell organelles. I’ll assign each student a certain slide… And [afterward] we will go through and play it like a game.” Angel also noted similar lessons on different topics. Because Angel demonstrated an effortless use of technology and individually paced student instruction, Angel would fall in between the levels of appropriation and invention.

Overall, the qualitative data from the interview and lesson plans indicated that these teachers were open and willing to use new technology. They indicate that they try to adapt technologies to their classrooms but would also appreciate science specific technology training.

**Mixed methods results**

Research question five was answered based on comparing both data sets. Each part of the research question will be described below. In accordance with an explanatory-sequential mixed methods study, the qualitative data was used to explain the quantitative results. For each section, the overall results will be summarized, followed by comparisons of the two data sets and how the qualitative data supports the quantitative data.

The creators of the TPACK-Deep scale found that the scale had four factors - design, exertion, ethics, and proficiency (Yurdakul et al, 2012, p. 972). In the sections below, these four factors were used to connect the qualitative and quantitative results.

**How secondary science teachers use technology in their classrooms.**

The TPACK-Deep survey results indicated that most of these teachers have a medium or high level of TPACK (see Table 10, page 55). A full list of each participants’ TPACK is available in Table 9 (page 53). The interview results demonstrated that the teachers use a variety
of hardware and software to meet the needs of their classrooms. They often adapt technology for their specific lessons.

One factor of the TPACK-Deep survey was design. The authors describe this factor as “teachers’ competencies in designing teaching to enrich the teaching process with the help of their technological and pedagogical knowledge about the content to be taught before the teaching process of the content” (Yurdakul et al, 2012, p. 969). The qualitative results support this factor because the interviewed teachers indicated that they could think about and adapt technology to meet the needs of their classrooms.

**Why secondary science teachers use technology in their classrooms.**

The qualitative data showed that the science teachers in this study recognize that technology was important in a 21st century classroom. They learn from their peers and were willing to learn more. They understand that technology was important for the real world, and they want to prepare their students to succeed in adult life.

The interview results did support the TPACK-Deep survey results. Teachers with a medium or high level of TPACK (as determined by the TPACK-Deep survey) have a solid understanding of the pedagogical uses of TPACK. As stated by the authors of the survey, “TPACK-Deep as framework is based on generic pedagogical strategies in terms of pedagogical and content knowledge” (Yurdakul et al, 2012, p. 973). This was supported by the results from the interviews because the participating teachers described a clear use of a variety of technologies in their classrooms, and they use those technologies to reach their pedagogical goals. The six interviewed teachers mentioned a range of technologies including Zoom, Jamboard, Schoology, and online videos (see Table 14, page 73), and how they used those tools within their classrooms.
To what extent do secondary science teachers report using technology in their classrooms.

Another factor of the TPACK-Deep scale was proficiency, or the “ability to integrate technology into content and pedagogy by becoming experts in the teaching profession” (Yurdakul et al, 2012, p. 970). By scoring high or medium on the TPACK-Deep survey, these teachers demonstrated that they could integrate technology as described previously (page 55).

Interview analysis for TCK and TPK demonstrated that the teachers already use technology in their classes. For example, multiple teachers talked about using iPads and Chromebooks (TCK) and using Google platforms, Schoology, Nearpod, and other software (TPK). See Table 14 (page 73) for more specific information on each participating teacher. All the interviewed teachers showed some level of technology adaptation within their lessons. Some of the teachers experimented with new ideas and demonstrated a focus on problem-based learning. This supports the results found in the TPACK-Deep survey. The teachers within this study did a majority of their technology learning on their own, and not through professional development offered through their school district.

Conclusion

The findings of this study showed that the teachers in these school districts were describing technology use in their classrooms. The results of the quantitative survey indicated that most of the teachers demonstrated a medium or high level of TPACK. Because the assumptions of ANOVA were violated, 95% CI were estimated to compare the mean TPACK scores between demographic categories of teachers classified by their teaching location (middle school, high school, or both), years of teaching science subjects, and science certifications from the State of Pennsylvania. The lower limits of the 95% CI of the point estimates of the mean
differences in the TPACK sum scores were negative, and the upper limits were positive, such that the confidence intervals captured zero (equivalent to \( p > .05 \)); however, the inclusion of zero scores within the CI did not imply that absolutely no differences existed. The positive values of the CI indicated that in 95% of the samples, the mean difference between the TPACK of approximately half of the teachers in each group would be greater than the point estimate. The negative values of the CI indicated that, in 95% of the samples, the mean differences between the TPACK of approximately half of the teachers in each group would be less than the point estimate. Therefore, it was not true to conclude that all groups of teachers who participated in this study had the same level of TPACK, with absolutely no differences between them. However, because not all grade levels or science certifications were represented in this data, it was impossible to conclude if these results apply to all teachers.

The qualitative results demonstrated that the teachers in these interviews value technology and see it as important for their science classrooms. Many noted that their peers were their best resources for learning about new technologies, but they wish that their schools would do more in terms of science specific professional development. They realized that there was technology available that may improve their teaching, and they were eager to use it in their instructional practices. Chapter 5 will discuss implications from the findings and recommendations for theory, research, and practice.
Chapter 5

Discussion

This chapter starts with a summary of the study, including a response to each research question. Next, implications for theory, research, and practice will be discussed. Finally, recommendations for theory, research, and practice, including recommendations for schools and districts, will be described.

Summary of the study

This study described secondary science teachers’ Technological Pedagogical Content Knowledge (TPACK) perspectives and experiences. Specifically, the purpose of this research study was to examine how, why, and to what extent in-service science teachers report using technology as part of instructional practices. The teachers who participated in the study may or may not have had a secondary science certification in the Commonwealth of Pennsylvania, but they were teaching a secondary science course at the time of the study.

This study was designed to answer the following research questions. One, is there a difference in technological content knowledge (TCK) or technological pedagogical knowledge (TPK) between science teachers in grades 7-12? Two, is there a difference in technological content knowledge (TCK) or technological pedagogical knowledge (TPK) between science teachers certified in different subject areas (i.e., biology, chemistry, etc.)? Three, how do secondary science teachers describe their levels of TCK or TPK? Four, how do secondary science teachers describe and/or explain how they use technology to support their specific content areas? Five, how does the analysis of both data sets (quantitative survey results and qualitative interview responses) help to describe how, why, and to what extent secondary science teachers report using technology in their classrooms?
The theoretical framework used in this study was TPACK, developed by Mishra and Koehler (2006). The TPACK-Deep survey, developed by Yurdakul, Odabasi, Kilicer, Coklar, Birinci, & Kurt (2012), was an extension of the TPACK model and was the survey used for this study. More information on the survey can be found in Chapter 3.

The methodology used in this study was an explanatory-sequential mixed methods design. The explanatory-sequential design was chosen for this study because it was important to go beyond the answers that teachers provided in a survey. By analyzing the explanation behind teachers’ answers, the researcher uncovered issues and potential solutions to technology integration in secondary science classrooms. For the quantitative data, the TPACK-Deep survey was used (see Appendix A). For the qualitative data, interview questions were formed (see Appendix C for interview protocols).

Differences in TCK and TPK between grade levels taught (RQ 1)

Research question one asked if there was a difference in technological content knowledge (TCK) or technological pedagogical knowledge (TPK) between science teachers in grades 7-12. To answer research question one, teachers were grouped into teaching only in a high school (grades 9-12) vs. teaching in any other setting (grades 7-8, or both 7-8 and 9-12) and teaching a shorter time (0-14 years) vs. a longer time (15-35 years). This grouping was necessary to calculate the confidence interval tests given the overall small sample size of participants. ANOVA was not used because the assumptions of ANOVA could not be satisfied. The mean TPACK sum scores for all categories of teachers were greater than 131, reflecting that overall, the group of teachers could be classified as high TPACK.

The positive values of the CI indicated that, in 95% of the samples, the mean difference between the TPACK of approximately half of the teachers in each group was greater than the
point estimate. The negative values of the CI indicated that, in 95% of the samples, the mean differences between the TPACK of approximately half of the teachers in each group was less than the point estimate. In summary, it can be concluded that there was some difference between each group, meaning there were some differences between the teachers teaching in a high school and teachers teaching in “other” settings (grades 7-8, or both 7-8 and 9-12). However, because of the small sample size, the researcher was unable to determine if the differences were statistically significant, or if these results would apply to every grade level taught. See Table 12 (page 61) for more information on the confidence intervals of these groups.

The researcher was not able to connect survey responses with specific interview participants. The survey was anonymous, while the interviews were not. It was not possible to connect the qualitative comments to the quantitative results. Therefore, the mixed methods results will have to remain generalizations to the whole group.

**Differences in TCK and TPK between science content area certifications (RQ 2)**

Research question two asked if there was a difference in technological content knowledge (TCK) or technological pedagogical knowledge (TPK) between science teachers certified in different subject areas (i.e., biology, chemistry, etc.). To answer research question two, teachers who reported having no science certification were compared to teachers who reported having one or more specific certifications. Again, this grouping was necessary to calculate the confidence interval tests given the overall small sample size of participants. There were not enough participants to group the teachers by subject area, and therefore research question two could not be answered with the data found in this study. According to the authors of the TPACK-Deep survey, a mean score of 131 or higher represented a high TPACK level. The mean TPACK sum scores for all categories of teachers classified by certifications were greater than 131, reflecting
that the teachers could be classified as high TPACK. The lower limits of the 95% CI below 131 mainly represented those teachers who were classified as medium TPACK. The positive confidence limits indicated that the TPACK of the teachers with no science certifications was greater than that of the teachers with science certifications. In summary, it can be concluded that there was some difference between teachers who had science certifications and teachers who did not have science certifications. However, because of the small sample size, the researcher was unable to determine if the differences were statistically significant. See Table 13 (page 63) for more information on the confidence intervals of these groups.

The researcher was not able to connect survey responses with specific interview participants. The survey was anonymous, while the interviews were not. It was not possible to connect the qualitative comments to the quantitative results. Therefore, the mixed methods results will have to remain generalizations to the whole group.

**Teachers describing their own use of TPACK (RQ 3)**

The qualitative results showed five themes – (a) needs for future professional development, (b) resource choice and needs, (c) importance of technology in the real world, (d) importance of technology in science instruction, and (e) the dynamic nature between technological content knowledge (TCK) and technological pedagogical knowledge (TPK). More information on each theme can be found in the qualitative results in Chapter 4 (page 65).

Three of the five qualitative themes help to illuminate how teachers describe their own TPACK: resource choice and need, importance of technology in science education, and the dynamic nature of TCK and TPK. “Dynamic” in this case means that TCK and TPK can look different for each classroom, but the two concepts were often grouped together in the minds of
teachers (Hofer & Harris, 2012; Yurdakul et al, 2012). These themes were determined by organizing the qualitative codes into similar groups.

When deciding which resources to use, teachers noted ease of use, resource availability, and peer recommendations. Several teachers agreed that peer recommendations help them to choose their resources. The teachers were open and willing to learn more about technology for science education, but they were also looking for guidance from their schools and peers. The software and websites used by these teachers represent a wide range of platforms and a creative use of available resources.

All the interviewed teachers agreed that technology was important in science education. Some of these teachers also agreed that technology increases their ability to differentiate to the students’ needs. The qualitative results indicated that these teachers were open and willing to use new technology. They try to adapt technologies to their classrooms but would also appreciate science specific technology training. Suggestions for how to meet this need will be addressed in the “recommendations” section below (page 92).

From the quantitative results, the participants’ TPACK sum scores indicated that the teachers who participated in the survey demonstrated a high level of TPACK. Descriptive statistics for the sum scores found a mean score of 134.36, with a standard deviation of 17.97. Scores above 131 were considered high TPACK, scores between 96 and 130 were considered medium TPACK, and scores below 95 were low TPACK (Yurdakul et al, 2012).

According to the authors of TPACK, a high level of TPACK can indicate two related concepts. First, it can serve as a measurement of the teacher’s TPACK knowledge, which can determine which training or professional development would best suit their needs (Mishra & Koehler, 2006, 1046). Second, it can explain what teachers need to know to make technology
integration successful in their classrooms (Mishra & Koehler, 2006, 1046). Given that the teachers who participated in this study have a high level of TPACK, it can be presumed that they already have a high level of knowledge in TPACK. Correspondingly, their future professional development will need to move beyond introductory technology topics. This idea will be explored further in the recommendations section (page 92).

**How science teachers use technology (RQ 4)**

Several of the interviewed teachers agreed that technology was essential in science education. The qualitative themes of “resource choice and need” and “importance of technology in science education” demonstrated that the participating teachers think critically about what technology they will use. Technology tools enhance their instruction by providing students multiple ways to learn and review content. Technology also empowers students to learn independently using the tools provided by the teacher, and it provides numerous methods for teachers to differentiate learning. Research, such as Jonassen (1998), supports the use of technology tools to engage learners in meaningful critical thinking.

Furthermore, the interviewed teachers noted how technology had been essential to their own growth and knowledge as a science educator. To make up for the lack of specific training in their subject areas, multiple teachers mentioned how they use outside sources like TikTok to learn more about science teaching. These ideas were shown in the qualitative themes of “describing past professional development” and “needs for future professional development.” These results were supported by the quantitative results. These teachers were using technology regardless of their grade level taught, number of certifications, or years of experience.
Describing how, why, and to what extent secondary science teachers report using technology in their classrooms (RQ 5)

The TPACK-Deep scale, which was the quantitative instrument for this study, breaks down its items into four factors – design, exertion, ethics, and proficiency (Yurdakul et al, 2012, p. 972). “Design” involves a teacher understanding how technology and pedagogy can enrich teaching content (Yurdakul et al, 2012, p. 969). “Exertion” describes a teacher’s ability to use technology for teaching purposes, and to evaluate the usefulness of technology for education (Yurdakul et al, 2012, p. 969). “Ethics” includes both professional ethics and technology ethics such as privacy (Yurdakul et al, 2012, p. 970). Finally, “proficiency” describes a teacher’s ability to integrate technology, pedagogy, and content; to solve problems that arise related to technology, pedagogy, or content; and choosing the most appropriate solutions (Yurdakul et al, 2012, p. 270). The four factors of the TPACK-Deep scale did reflect the qualitative findings of this study and will be used to connect the two data sets.

The first factor for the TPACK-Deep survey, “design,” was reflected in the qualitative themes of “resource choice and need” and “importance of technology.” The interviewed teachers demonstrated a clear understanding of what technology was best for their students. They were able to design lessons that both teach their content and teach technological skills.

The second factor, “exertion,” was shown in the themes of “resource choice and need” and “the dynamic nature of TCK and TPK.” (Dynamic was used here to mean that TCK and TPK can look unique in different classrooms. There was no one correct way to demonstrate TCK and TPK.) The interviewed teachers researched and chose the best technology for their needs. They were able to measure the effectiveness of their chosen methods and adapt as needed.
The third factor, “ethics,” was demonstrated in the theme of “importance of technology.” Teachers understand that their students need to know how to use technology correctly. Technology will be an integral part of their futures, both in science classes and elsewhere. They showed a desire to choose the best technological tools to meet the needs of both their instruction and their students.

The fourth factor, “proficiency,” was shown in all of the themes. The teachers demonstrated that they were experts in TPACK by their clear integration of technology and the importance they placed on technology in science education. They were able to solve problems by looking for professional development and recognizing where their schools could do better with teacher learning around the use of technology. They could choose the best resources and they know which methods were the best to use for their students.

When the TPACK-Deep model was broken down according to the four factors, it was clear to see that the teachers who participated in this study already have a solid foundation of TPACK from which they build their lessons. They also recognized that they could learn more, which will be discussed below (page 92) in the recommendations section.

**Implications**

In this section, the research findings will be discussed in the context of implications for theory, research, and practice. Implications for theory includes TPACK in general, and the TPACK-Deep survey specifically, in terms of how useful these methods were for studying teachers in similar contexts. Implications for research illustrates the mixed methods design that was used in this study and its suitability for other studies similar to this research. Implications for practice describes what the results of this study mean for the science teachers in the research area.
Implications for theory

Confidence intervals reported in Chapter 4 revealed that the TPACK-Deep survey was able to show some difference between teachers’ TPACK in terms of their grade levels (i.e., grades 7-8, 9-12, or 7-12) and certifications (no science certifications vs. one or more science certifications). As shown in the summary section above (page 88), the mixed methods results also indicated that the interviewed teachers (qualitative results) demonstrated a strong foundation of TPACK skills, which was reflected in the survey (quantitative) results. Overall, the TPACK-Deep survey was an effective tool for measuring teachers’ TPACK and for revealing differences between groups of teachers, although the sample sizes were too small to effectively measure significant differences between all of the intended teacher groups.

Implications for research

The explanatory-sequential mixed methods design of this study worked well, particularly in the context of practitioner research with teachers. The survey information demonstrated that these teachers all had some level of knowledge with TPACK. The interview answers helped to highlight areas where teachers reported succeeding and where teachers reported struggling with technology use in their classrooms. The two data sets together were critical to understanding exactly where teachers need more support.

The survey alone would have demonstrated that the teachers have high TPACK knowledge but would not have shown what supports and resources the teachers need to improve their use of technology. As a result of the small sample size, the results from the survey were inconclusive. It would have been difficult to describe what these teachers need, and to recommend ideas for the future, from inconclusive results alone. Therefore, the research design was critical in illuminating the perspectives of these teachers.
Twenty-two teachers responded to the survey, representing 41.5% of the fifty-three total grades 7-12 science teachers in the four participating school districts. Six of the twenty-two teachers, from three of the four participating districts, were interviewed. The participant numbers were lower than expected because of many factors such as Covid restrictions and scheduling issues. The analysis of the data would be stronger if more teachers had participated. Classroom observations were not a part of data collection for this study, but observations may be a useful extension of this study in the future.

**Implications for practice**

This study contributed to the greater research community by validating a mixed methods approach to understanding science teacher’s TPK and TCK. In addition, the study utilized practitioner research, seeking to address a contextualized problem of practice. The goal of this research was to inform professional development around the use of technology for science teachers through understanding what they already know and do, and through discovering opportunities for future professional learning.

The data collected from these teachers shows that, overall, they have a solid knowledge of TPACK. Among the twenty-two teachers, the majority (twelve, or 54.5%) were classified as high TPACK, while nine (30.9%) were classified as medium TPACK, and only one (4.5%) was classified as low TPACK (sum score = 86).

Qualitative analysis of the interview showed that the teachers in these interviews value technology and see it as important for their science classrooms. Many noted that their peers were their best resources for learning about new technologies. Concerning past professional development, none of these teachers had training in technology use specifically for science
education. They realized that more current or more appropriate technology was available, and they were eager to use it in their instructional practices.

The overall picture shows that these teachers were knowledgeable in technology, but they want to learn more. From the participants’ perspective, the districts were not doing enough to help them utilize technology in their science classrooms. The teachers in this study explained that they rely on peers for help. They feel that their districts need to do more. Recommendations for how to achieve this goal can be found in the next section.

**Recommendations for theory, research, and practice**

In this section, the researcher will explain recommendations for the future in terms of theory, research, teacher education, and practice. Theory recommendations will explain how TPACK and the TPACK-Deep survey can be useful for future studies. Research recommendations will include how the explanatory-sequential mixed methods research method, as well as the specific research questions and methods used in this study, can be used and adapted for future work. Recommendations for teacher education will contain ideas for how university professors can help preservice teachers to improve their content specific technology use. Practice recommendations will include how teachers and districts within this study can achieve their technology goals.

**Recommendations for theory**

Quantitative analysis demonstrated that the TPACK-Deep survey was indeed able to differentiate between different groups of teachers, although the data was not statistically significant because of the small sample size. The next step would be to replicate the study with more participants so that stronger quantitative analysis can be performed. The TPACK-Deep
survey was a reliable instrument that can help researchers to examine different groupings of teachers.

**Recommendations for research**

An explanatory-sequential research design was used within this study. It is a form of mixed methods research in which the qualitative data is used to explain the quantitative results (Creswell & Plano Clark, 2007). This study design worked well, especially with the smaller sample size. The interviews helped the researcher to understand the TPACK-Deep survey results and how TPACK use looks in a real classroom. Because of the small sample size, the results of the statistics were inconclusive. Without the qualitative data and the explanatory-sequential design, it would have been difficult to determine what this group of teachers needs in order to be successful. In the future, this design would be beneficial to use in order to understand survey results in a deeper, more meaningful way.

There were some problems that occurred within this study that should be corrected when the study is replicated. After participants completed the TPACK-Deep survey, they were directed to input their demographic information. The researcher did not include a question about which science classes the participants were currently teaching. As a result, data could not be analyzed on specific content areas, and was limited to only how many science certifications each participant held for the Commonwealth of Pennsylvania. In addition, because of the small sample size, statistical analysis could only be performed on two groups – had science certifications vs. did not have science certifications. This made the quantitative analysis more complex because teachers may be teaching in a science course where they were not specifically certified. There could be several reasons why teachers would not be certified for the classes they are teaching. For example, industry professionals may be applying for an emergency certificate,
or teachers who are still in training may be allowed to teach while getting their degree. The researcher was not able to verify why teachers who responded to this study may not have been certified to teach science in the Commonwealth of Pennsylvania. It also presented a problem when several participants marked that they had none of the listed certifications, or that they were not certified to teach science at all. This could be corrected by a more careful attention to the demographic questions in potential surveys.

**Recommendations for teacher education**

This study also illuminated potential areas of change for teacher education programs. The teachers included within this study did have some technology training, whether from their teacher education programs, from their school districts, or from their peers. Similarly, teachers in graduated from teacher education programs will have some knowledge of technology use in education from their own time as students. According to Dexter, Doering, and Reidel (2006) “even if preservice teachers know how to operate technology, they need help to understand how to flexibly incorporate new technology resources into their knowledge of a content area in ways that enhance student learning” (p. 325). Kolb (2017) agrees that “effective technology integration is only as good as the instructional practices used within and around the tool” (p. 162). In the Dexter, Doering, and Reidel (2006) article, the authors followed a preservice education program at a university which integrated technology use into content specific learning. Preservice teachers learned about content specific technology by watching their professors use of technology. Based on this study and others, a recommendation for preservice teacher programs can be to teach professors to actively use educational technology within their own classes. That way, the students (preservice teachers) can learn by observing and by doing.
Recommendations for practice

The driving purpose behind this research study was to discover what science teachers need in terms of professional development in the use of technology in secondary science classes. According to the National Science Teaching Association (NSTA), science teacher professional development should “be assessed and refined to meet teachers’ changing needs” (2022a). NSTA also supports “ongoing professional development opportunities and effective preservice and induction programs for science educators support the integration of 21st-century skills in classroom teaching” (2022b). The surveys and interviews conducted in this study were helpful in determining the teachers’ current TPACK knowledge. Now that the TPACK of the participating teachers was understood, recommendations can be made about what should happen next to advance their TPACK.

Multiple studies in the past five years have demonstrated methods to improve teacher TPACK. Sripan and Sujivorakul (2020) used technology-based guided inquiry to improve biology student teachers’ TPACK. Njiku, Mutarutinya, and Maniraho (2021) used collaborative lesson design activities to develop math teachers’ TPACK. In an analysis of thirteen studies on higher education online teaching, Major and McDonald (2021) stated “educators can improve their TPACK by studying and training, practicing, working with peers and colleagues, examining the effect on their students, and sharing their own results” (p 64). Clearly, there is no one correct way to help teachers improve their TPACK. Suggestions for the teachers included in this study are described below.

The teachers in this study indicated that they have not had much professional development in terms of the use of technology specifically for science classes. Several reasons could explain why this happened. Training in scientific tools usually happens when teachers
were in their undergraduate programs. However, teacher education programs can vary widely even within the same state, and teachers may not have been exposed to TPACK training specifically. Within their professional work, it may be outside of the scope of a school district to offer training on more advanced technologies. In addition, school wide technology and training was limited to what can impact the most teachers, or what can be used by the most people for the least amount of money. Some universities offer outreach programs that could be useful in professional development. For example, The Center for Science and the Schools provided by Penn State University offers professional development in updated content knowledge, assists teachers participating in field research, and offers STEM activities for schools (Penn State College of Education, 2022). These types of activities can be invaluable to teachers as they seek to continue their scientific knowledge and its application to teaching. Programs like these can be expensive, may only allow a limited number of participants, or may be limited to certain places or times, which would prohibit more teachers from taking advantage of such options.

Several teachers within the interviews mentioned that they learn a great deal from their peers. Using this willingness to teach and learn from colleagues would be the easiest solution for the school districts in this study. There were dozens of science teachers within these districts alone. A large group professional development session, or even a small collaborative session, where all of the teachers share their knowledge would be undoubtedly helpful for all.

In addition, teacher knowledge sharing was supported by research. An article by Van Acker, Van Burren, Kreijns, and Vermeulen about teacher sharing educational resources stated, “by recycling other teachers’ ideas, teaching activities may improve and course preparation time could possibly be reduced” (2013, p. 178). In a 2019 study of rural teachers, Karnopp found that
“by galvanizing teachers around a shared goal, school principals can leverage educators' motivation to engage in knowledge-building, and thus enhance organizational learning.”

Teachers have a great deal of knowledge that they were not always able to share because of time and space constraints. If their districts provide this time for them, the teachers will be more likely to share and interact over time.

**Conclusions**

This practitioner research study discovered that the teachers within the study area were knowledgeable about technology use within their classrooms. They use technology in many ways, but they would like to learn more. Often, this new knowledge comes from their peers. While there were some teacher professional development programs available, it would be most effective for the school districts in this study to leverage this sharing of knowledge into a professional learning community. Give the teachers the time and space to learn from each other. These districts have the power to foster these professional relationships and help all teachers improve their practice.
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### Appendix A

TPACK-Deep Survey

From Yurdakul et al (2012); Used with permission

The purpose of this section is to gather information about combining technology, pedagogy and content knowledge in the teaching and learning process. For each item, choose only one option (Strongly Disagree, Disagree, Neither Agree or Disagree, Agree, Strongly Agree) that best describes you. Please answer all of the questions and if you are uncertain of or neutral about your response you may always select “Neither Agree or Disagree”.

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</table>
The purpose of this section is to gather information about combining technology, pedagogy and content knowledge in the teaching and learning process. For each item, choose **only one option** (Strongly Disagree, Disagree, Neither Agree or Disagree, Agree, Strongly Agree) that best describes you. Please answer all of the questions and if you are uncertain of or neutral about your response you may always select "Neither Agree or Disagree".

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
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</thead>
<tbody>
<tr>
<td>25</td>
<td>I can use technology in every phase of the teaching and learning process by considering the copyright issues (e.g., license)</td>
<td>☐</td>
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<td>26</td>
<td>I can follow the teaching profession’s codes of ethics in online educational environments (WebCT, Moodle, etc.)</td>
<td>☐</td>
<td>☐</td>
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<td>27</td>
<td>I can provide guidance to students by leading them to valid and reliable digital sources.</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>28</td>
<td>I can behave ethically regarding the appropriate use of technology in educational environments.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>29</td>
<td>I can troubleshoot problems that could be encountered with online educational environments (WebCT, Moodle, etc.)</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>30</td>
<td>I can troubleshoot any kind of problem that may occur while using technology in any phase of the teaching-learning process</td>
<td>☐</td>
<td>☐</td>
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<td>☐</td>
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<tr>
<td>31</td>
<td>I can use technology to find solutions to problems (structuring, updating and relating the content to real life, etc.).</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>32</td>
<td>I can become a leader in spreading the use of technological innovations in my future teaching community.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>33</td>
<td>I can cooperate with other disciplines regarding the use of technology to solve problems encountered in the process of presenting content.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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</table>
Appendix B

Permission to use TPACK-Deep Survey

Good evening,

I am a doctoral student at Duquesne University. I am looking to study TPACK in secondary science and math teachers. A fellow student suggested that I use the TPACK-deep survey. Would it be okay for me to use the survey for my research?

Thank you!

- Stefanie Graban

Işil KABAKÇI YURDAKUL <isilk@anadolu.edu.tr>
Mon 8/5/2019 8:03 AM
Stefanie Graban ⚪

Dear Stefanie Graban,

You have my permission to use TPACK-deep scale in your research about secondary science and math teachers’ TPACK. This permission given to you through this form is valid just for you.

Best wishes in your work.

Associate Professor
Işıl Kabakçı Yurdakul, PhD
Department of Computer Education and
Instructional Technologies
College of Education
Anadolu University, TURKEY
Appendix C

Interview Protocols

Good afternoon! My name is Stefanie Graban. I am a science teacher in a local school district and a doctoral student at Duquesne University in the Instructional Technology and Leadership program. I am currently working on my dissertation research about science teacher’s use of technology in their classrooms. You have been selected because you are a secondary science teacher in south-central PA.

To facilitate notetaking, I would like to audio tape the conversation today. Please sign the release form. Only researchers on this project will be able to hear or read your responses, and all recordings will be deleted once they are transcribed. Your personal information will be deidentified. I have planned this interview to last about one hour. The first part of the interview will ask you general questions about your background, and the second part will focus on a lesson plan or other learning material that you have brought with you today.

Introduction to the Interview Process

My research project focuses on secondary science teachers and how they use technology within their classrooms. You have already responded to the TPACK survey that was sent to you through email. That survey data, along with the responses from these interviews, will be used to determine the level of TCK (technological content knowledge) and TPK (technological pedagogical knowledge) that exists in the districts being studied. The goal is for this data to be used to inform professional development within your district and other participating districts. My study will not evaluate you as a teacher. I am attempting to learn more about teaching and learning through the use of technology, and hopefully to drive new professional learning in your district.
As you respond to these questions, please keep in mind that I am interested in your typical classroom environment. You may leave out anything that has changed in terms of your use of technology as a result of virtual learning due to Covid-19.

**Interviewee Background**

1. What grade level(s) do you teach? What courses do you teach?
2. How long have you been at this school? How many total years have you been teaching in your certified subject area?
3. What is your specific field within science? What certifications do you hold? Do you have multiple certifications?
4. Describe any other roles that you have that relate to student learning (i.e., coaching, club sponsorship, etc.).
5. In the past, have you ever participated in district-level professional development about the integration of technology in your specific subject area? If so, can you tell me more about it?
6. In the past, have you ever participated in other professional development (outside of your school district) about the integration of technology in your subject area? If so, can you tell me more about it?
7. What are some technology topics that you would like to learn more about through district-level professional development? (For example, how to use specific tools.)

**Artifact Review** (adapted from Standish, 2012 and Campbell & Abd-Hamid, 2013)

1. Tell me about the artifact you brought. What course is it from? What grade level are the students?
2. How do you specifically use technology in this lesson? Are there any specific tools that you use?

3. How do you decide to use a resource like [name of technology]?
   a. What resources did you use to select this technology? (i.e., website, recommendations)
   b. When selecting a technology to use, what do you consider? What must this technology have or be able to do?

4. In your opinion, why is technology important in science education?

5. What does technology integration mean to you as a science teacher?

6. Think about your specific subject areas. How does technology help students to learn your subject area? What does technology do that could not be done any other way?

7. If you did not have technology available, how would you teach this content?
   a. What are the particular features of this technology that help you to reach your instructional goals?

8. Do you think that you have the technology resources necessary to support teaching in your content area? If not, what would you like to have?
Appendix D

Figure 2 permission

<table>
<thead>
<tr>
<th>Email Address:</th>
<th><a href="mailto:grabans@dun.edu">grabans@dun.edu</a></th>
</tr>
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<tbody>
<tr>
<td>Phone type:</td>
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<tr>
<td>Brief Description:</td>
<td>I am a doctoral student, just finishing up my dissertation. I used a part of the education directory maps <a href="https://www.education.pa.gov/Pages/Education-Directory-and-Maps.aspx">https://www.education.pa.gov/Pages/Education-Directory-and-Maps.aspx</a> as a figure in my writing. My university requires that I obtain permission to use this image. I am not sure who to ask for this. Is it possible for me to get permission through this form? Or can you direct me to who I would need to ask? Thank you!</td>
</tr>
</tbody>
</table>

---

Bazzo, Kelly <kbazzo@pa.gov>

To: Stefanie Graban

Hi Stefanie,

You are good to use anything on that page in your work. Have a wonderful holiday weekend!

---

**Kelly Choi Bazzo** | Digital Director
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(717) 649-4786
www.education.pa.gov
twitter.com/PADeptofEd | facebook.com/PADepartmentofEducation
pinterest.com/PADepOfEd | youtube.com/PADepOfEd