TPACK Development in Science Teacher Preparation:

A Case Study in Queensland, Australia

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This dissertation titled

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Abstract

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TPACK Development in Science Teacher Preparation: A Case Study in Queensland, Australia.

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This study sought to identify key experiences that impact the development of technological pedagogical content knowledge (TPACK) of preservice secondary sciences teachers at a medium-sized university in Queensland, Australia. TPACK is a conceptual framework of a body of knowledge that teachers draw upon to influence practice; it is a dynamic and emergent form of knowledge that informs the employment of technology for teaching specific subject matter.

This study employed an embedded case study approach, including delivery of a TPACK survey instrument and analysis of participant interviews, to identify the context-specific experiences that promote the development of TPACK among twelve preservice secondary science teachers. The research addresses a specific need cited in the literature, identifying TPACK impact factors, and provides a novel way to visualize TPACK development through contextual experiences.

A novel approach to visually representing context-specific experiences and their influence on teacher knowledge, self-efficacy, values and beliefs was employed. Three major findings are presented below: 1) the majority of preservice secondary science teachers were unable to define the constructs of learning and science; 2) a focus on
motivation and interest paired with a disconnect between expressed and enacted pedagogical orientation lead to teacher-centered instruction augmented with superficial tactics aimed at generating interest; and 3) difficulty in integrating knowledge bases yielded lower TPACK self-efficacy, which has detrimental impacts on the instruction planned by pre-service teachers for their students. Findings are directly aligned with participants' prior experience, compared to the relevant literature, and utilized to identify implications for teacher preparation as well as recommendations for future research.

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I would like to dedicate this work to my Papaw...this is my Olympics ;)}
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# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>3</td>
</tr>
<tr>
<td>Dedication</td>
<td>5</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>6</td>
</tr>
<tr>
<td>List of Tables</td>
<td>12</td>
</tr>
<tr>
<td>List of Figures</td>
<td>13</td>
</tr>
<tr>
<td><strong>Chapter 1: Introduction</strong></td>
<td>15</td>
</tr>
<tr>
<td>Statement of the Problem</td>
<td>15</td>
</tr>
<tr>
<td>Purpose of the Study</td>
<td>17</td>
</tr>
<tr>
<td>Research Questions</td>
<td>18</td>
</tr>
<tr>
<td>Significance of the Study</td>
<td>19</td>
</tr>
<tr>
<td>Definition of Terms</td>
<td>22</td>
</tr>
<tr>
<td>Contextual terminology differences</td>
<td>25</td>
</tr>
<tr>
<td>Organization of the Study</td>
<td>27</td>
</tr>
<tr>
<td><strong>Chapter 2: Literature Review</strong></td>
<td>29</td>
</tr>
<tr>
<td>The TPACK Framework</td>
<td>30</td>
</tr>
<tr>
<td>Conceptual components</td>
<td>30</td>
</tr>
<tr>
<td>Technological knowledge (TK)</td>
<td>30</td>
</tr>
<tr>
<td>Content knowledge (CK)</td>
<td>31</td>
</tr>
<tr>
<td>Pedagogical knowledge (PK)</td>
<td>31</td>
</tr>
<tr>
<td>Pedagogical content knowledge (PCK)</td>
<td>32</td>
</tr>
<tr>
<td>Technological content knowledge (TCK)</td>
<td>34</td>
</tr>
<tr>
<td>Technological pedagogical knowledge (TPK)</td>
<td>34</td>
</tr>
<tr>
<td>Technological pedagogical content knowledge (TPACK)</td>
<td>35</td>
</tr>
<tr>
<td>Ambiguity of boundaries</td>
<td>37</td>
</tr>
<tr>
<td>Varying perspectives</td>
<td>39</td>
</tr>
<tr>
<td>The ‘T’ in TPACK</td>
<td>39</td>
</tr>
<tr>
<td>Integrative vs. transformative views</td>
<td>41</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td>43</td>
</tr>
<tr>
<td>The Teaching Apprenticeship</td>
<td>45</td>
</tr>
</tbody>
</table>
Gaps in the Literature ................................................................. 47
Chapter 3: Methodology ............................................................ 51
Rationale for Selected Case .......................................................... 51
Description of Context ............................................................... 54
  Program structure. ................................................................... 57
  Undergraduate program. ............................................................ 57
  Grad Dip program ................................................................... 58
Course structure. ....................................................................... 59
Context and Sample ................................................................... 60
Sampling plan. .......................................................................... 61
Data Collection Procedures ....................................................... 65
  Survey instrument. .................................................................. 67
  Interview protocol. ................................................................... 68
  Document collection. ............................................................... 71
Data Analysis Procedures .......................................................... 72
  Field notes and document analysis. .......................................... 72
  Analysis of survey data. .......................................................... 73
  Analysis of interview data. ....................................................... 74
  Visualization of interview data. ............................................... 81
Credibility ................................................................................ 82
Chapter Summary ..................................................................... 90
Chapter 4: Findings ................................................................. 91
Diagnostics ................................................................................ 92
Research Question 1 ............................................................... 94
Beliefs regarding technology. .................................................... 94
  Affordances ........................................................................... 94
  Constraints. ........................................................................... 97
  Considerations. ................................................................. 98
Beliefs regarding pedagogy. ..................................................... 99
  Conception of learning ......................................................... 99
Teacher role. ........................................................................... 100
The pairing of teacher-centered instruction with superficial motivation........ 169
Related experience. .............................................................................. 171
Relevant literature. ............................................................................. 173
Implications for teacher preparation. .................................................. 176
Finding 3: Integration Issues............................................................... 177
Evidence............................................................................................. 177
The difficulties of integrating knowledge bases................................. 177
Self-efficacy impacts instructional planning........................................ 178
Related experience.............................................................................. 179
Underdeveloped technology-related forms of knowledge....................... 179
Pedagogical-related forms of knowledge.............................................. 179
Content-related forms of knowledge.................................................... 180
Relevant literature.............................................................................. 180
Implications for teacher preparation.................................................. 184
An integrated approach to TPACK development.................................. 184
Exploiting the value of practical experience......................................... 184
Recommendations for Future Research.............................................. 185
The need to investigate experience as sources of TPACK development..... 185
A visual model for representing contextual knowledge origins............... 185
Investigating best practices for integrated TPACK development............ 186
A practical focus in TPACK research................................................... 186
Conclusion.......................................................................................... 187
References......................................................................................... 189
Appendix A: IRB Approval................................................................. 215
Appendix B: Survey of Preservice Teachers' Knowledge of Teaching and Technology.................................................................................. 216
Appendix C: Permission to Use Survey of Preservice Teachers' Knowledge of Teaching and Technology.......................................................... 221
Appendix D: Semi-Structured Interview Protocol.................................. 222
Appendix E: Permission to Use TPACK Diagram.................................. 224
## List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>Prac Schedule for Undergraduate Program</td>
<td>58</td>
</tr>
<tr>
<td>Table 2</td>
<td>Prac Schedule for Grad Dip Program</td>
<td>59</td>
</tr>
<tr>
<td>Table 3</td>
<td>Reliability of the TPACK Questionnaire Scores</td>
<td>67</td>
</tr>
<tr>
<td>Table 4</td>
<td>Coding Structure of Beliefs, Sources and References</td>
<td>75</td>
</tr>
<tr>
<td>Table 5</td>
<td>Coding Structure of Self-Efficacy, Sources and References</td>
<td>77</td>
</tr>
<tr>
<td>Table 6</td>
<td>Coding Structure of Contexts, Sources and References</td>
<td>78</td>
</tr>
<tr>
<td>Table 7</td>
<td>Coding Structure of TPACK, Sources and References</td>
<td>79</td>
</tr>
<tr>
<td>Table 8</td>
<td>On a didactic prerequisite to teaching and learning</td>
<td>104</td>
</tr>
<tr>
<td>Table 9</td>
<td>Characteristics for Scale Scores (N=12)</td>
<td>109</td>
</tr>
<tr>
<td>Table 10</td>
<td>Impacts of Self-Efficacy in Planning for Instruction</td>
<td>118</td>
</tr>
<tr>
<td>Table 11</td>
<td>TPACK References in University Contexts</td>
<td>122</td>
</tr>
<tr>
<td>Table 12</td>
<td>On a the Disconnect Between Espoused and Enacted TPACK-related Values</td>
<td>134</td>
</tr>
<tr>
<td>Table 13</td>
<td>TPACK References in Contexts Beyond the University</td>
<td>137</td>
</tr>
<tr>
<td>Table 14</td>
<td>On Piecing Together TPACK</td>
<td>156</td>
</tr>
</tbody>
</table>
List of Figures

Page

Figure 1: Embedded case study design.................................................................62

Figure 2: Perceived affordances of technology..................................................96

Figure 3: Perceived constraints of technology....................................................98

Figure 4: Low self-efficacy references by context.............................................111

Figure 5: Moderate self-efficacy references by context....................................112

Figure 6: High self-efficacy references by context............................................112

Figure 7: Self-efficacy references to content knowledge by context..................113

Figure 8: Self-efficacy references to pedagogical knowledge by context..........114

Figure 9: Self-efficacy references to technological knowledge by context........114

Figure 10: Self-efficacy references to pedagogical knowledge by context.........115

Figure 11: Self-efficacy references to technological pedagogical knowledge by context.................................................................116

Figure 12: Self-efficacy references to technological pedagogical content knowledge by context.................................................................117

Figure 13: Self-efficacy references to technological content knowledge...........117

Figure 14: Positive TPACK-related experiences in university context............124

Figure 15: Grad Dip and undergraduate TK references by university context.....125

Figure 16: Grad Dip and undergraduate TK references by university context.....126

Figure 17: Negative TPACK-related experiences in university context.............128

Figure 18: Positive and negative TPACK-related experiences in university context........................................................................................................129

Figure 19: Consolidated TPACK-related experiences in university context.....130
Figure 20: Participant-reported frequency of TPACK modeling in university context.

Figure 21: TPACK references across all contexts (positive, negative and lacking).

Figure 22: Positive TPACK-related experiences across all contexts.

Figure 23: Negative TPACK-related experiences across all contexts.

Figure 24: Positive and negative TPACK-related experiences across all contexts.

Figure 25: Consolidated TPACK-related experiences across all contexts.

Figure 26: Consolidated TPACK-related experiences, all contexts, university parsed.

Figure 27: Orientation by context.

Figure 28: TPACK model reproduced by permission of the publisher, © 2012 by tpack.org.

Figure 29: TPACK-related experiences in preservice secondary science teacher preparation program.
Chapter 1: Introduction

Statement of the Problem

As the U.S. strives to remain competitive in a knowledge- and innovation-driven global economy, the preparation of quality K-12 teachers, specifically in STEM fields, is a critical issue (ACT, 2013; Committee on STEM Education National Science and Technology Council, 2013). The teacher has been shown to be the single greatest determinant, at least in the school context, of a student’s educational experience (Kane, Taylor, Tyler, & Wooten, 2011; McNeil & Krajcik, 2008). NETP (U.S. Department of Education, 2010) states that “Effective teaching is an outcome of preparing and continually training teachers and leaders to guide the type of learning we want in our schools” (p. 5). As such, teacher preparation in the STEM fields is an essential focus. The U.S. Federal Budget Request allocated $3.4 billion to STEM education programs in 2012, and President Obama has called for 100,000 STEM teachers to be prepared with sound pedagogy and deep content knowledge in the next decade (What Makes for Successful, 2011). The National Mathematics Advisory Panel has, furthermore, cited a lack of detailed findings on key facets of successful teacher preparation programs (Flawn, 2008), and the President’s Council of Advisors on Science and Technology and the National Research Council have called for research that identifies successful characteristics of such programs (President’s Council of Advisors on Science and Technology, 2010).

This case study helps to address this call; it examined the development of Technological Pedagogical Content Knowledge (TPACK) in the secondary science teacher preparation program at a medium-sized university in Queensland, Australia. The
intent of the study was to identify key program characteristics, as cited as a need in the literature on science teacher preparation, and to gain insight into factors, both internal and external to the university context, which shape the development of this specialized form of knowledge. A focus on TPACK has the potential to not only contribute to the field of instructional technology, but to inform teacher education in STEM fields as well.

A teacher preparation program at an Australian university was selected as the research site, as Australia has recently established a national curriculum with a strong focus on the integration of information communication technologies (ICTs). In order to re-align teacher preparation programs with the new curriculum, a nationally-funded effort – the Teaching Teacher for the Future (TTF) program – has been developed to better prepare teachers to effectively employ ICTs for teaching and learning (see Chapter 3, Description of Context). While the initial intent was an intrinsic case study, due to the fact that TTF outcomes had not been implemented in the research context, it was found that the case was typical to many Australian and even U.S. teacher preparation programs (see Rationale for Selected Case, Chapter 2); thus emergent design was embraced and the study sought to identify findings that may prove transferable to similar contexts.

Although the study was conducted in Australia, it is anticipated that the findings can inform teacher preparation programming in the U.S., as the general approach to teacher preparation are largely similar across both countries (Dinham, 2015; Tobin, 2011). As teacher preparation becomes more globalized, it is likely that readers from contexts around the world can identify implications from international studies that transfer to their own contexts (Olmedo & Harbon, 2010). Furthermore, given the new national curriculum
and the push toward better preparing preservice teachers to effectively with information communication technologies (ICTs), findings from this work will be of interest to policymakers in Australia.

**Purpose of the Study**

The purpose of this study is to identify key experiences that impact the development of technological pedagogical content knowledge (TPACK) of preservice secondary sciences teachers. TPACK is founded on Shulman’s (1986) construct of pedagogical content knowledge (PCK), a framework for teacher knowledge. PCK is familiar and widely considered in the preparation of science teachers (Aydin & Boz, 2012; Nezvalová, 2011). Teachers today are charged with preparing students with 21st Century skills, which include the ability to harness new technologies in a variety of contexts and for varying purposes (Niess, 2008). TPACK allows teachers to conceptualize and deliver effective learning experiences informed by their knowledge of technology, pedagogy, content, learners, and context (Angeli & Valanides, 2008). The National Educational Technology Plan (NETP) recognizes that today’s students must be prepared to productively navigate a global economy, and collaborating across borders and cultures. NETP cites a widening disconnect between students’ school and real world experiences and acknowledges technology (a term defined below) as a potentially transformational driver of change in education (U.S. Department of Education, Office of Educational Technology, 2010). In order to effectively integrate technology into educational experiences, teachers must be prepared with a sound understanding of their
content area, effective strategies to teach this content to their learners in context, and use informed approaches to using technology.

**Research Questions**

Creswell (1998) recommends reducing a study to one, overarching question with multiple subquestions. The central question guiding this study is:

What are the key factors that influence the development of TPACK among preservice science teacher candidates at this Queensland university?

Subquestions also refer specifically to the context of case (i.e., the medium-sized university in Queensland, Australia). These include:

1. What are the beliefs of preservice science teachers regarding technology, pedagogy and content?
2. What are the levels of self-efficacy of the preservice teacher candidates regarding TPACK and what experiences are shaping these?
3. To what extent has TPACK been developed through experiences in the secondary science teacher preparation program?
4. What sources of TPACK do preservice science teachers draw upon in planning for instruction?

These questions were broken down further to examine each aspect of TPACK as it relates to science education during analysis; for example, subquestion 2 envelopes issues such as whether preservice teachers value technology integration and whether they view it as part of their responsibility to teach (technology), what they believe about teaching and learning and their considerations for selecting approaches to instruction (pedagogy), and
how they conceptualize science as a content area (content knowledge). Interactions between these components (e.g., technology as it is viewed/employed specifically for science education) were also investigated. As teaching is a practice, it is important to relate teachers’ knowledge (TPACK) with their relevant beliefs (Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2012).

It is worthwhile to note that, in light of the nature of emergent design, these were working research questions. Emergent design flexibility is the “openness to adapting inquiry as understanding deepens and/or situations change;” Patton explains that this allows the researcher to “pursue new paths of discovery as they emerge” (Patton, 2002, p. 40).

**Significance of the Study**

The significance of this research across the fields of instructional technology and teacher education have been previously detailed. The need for research on the influence of preservice teachers’ TPACK-related beliefs (Niess, 2008) and TPACK development in specific contexts (McCory, 2008) has been noted. This study provides a necessary first step in identifying specific characteristics that impact TPACK development in science teacher preparation programs. While generalizability is not typically touted as a primary concern of case studies, Hellström (2006) argues that generalizability, as conceptualized for natural science and naturalistic social science, is applicable to such qualitative research. Likewise, Berg (2004) asserts that well-executed case studies should not only provide insight into the specific context and participants in the case, but should “also generally provide understanding about similar individuals, groups, and events” (Berg,
2004, p. 259). There is undoubtedly great potential for what Stake (1994) terms naturalistic generalization or Lincoln and Guba (2000) discuss as transferability; that is, readers may determine what aspects of the current study are applicable to outside contexts. Shadish (1995) notes that such generalizability can be guided by Cook’s (1990) five principles of logic: 1) proximal similarity (i.e., the degree of likeness between the research context and our own); 2) heterogeneity and irrelevancies (i.e., when findings hold across various conceptually irrelevant variables; 3) discriminant validity (i.e., the degree of certainty that the target construct – and not a rival explanation - is yielding the finding); 4) interpolation and extrapolation (i.e., the ability to accurately predict and verify how differing variables will impact the findings); and 5) explanation (i.e., the ability to isolate essential components and processes and accurately predict their impact on the context to which we wish to generalize) (pp. 424-426). Thick description will aid the reader with such determinations.

Schrum et al. (2007) note, “Until the pedagogical methods that uniquely take advantage of a technology’s pedagogical affordances to achieve content-specific learning objectives are identified, it will not be possible to prepare teachers to make effective use of current and emerging technologies” (p. 460). This study aids in bringing TPACK into the discussion among science teacher educators, as PCK is the typical focus in the field at present, the technology aspect generally being reserved for study within educational/instructional technology research. While it may seem logical that TPACK would be the focus over the more limited PCK, especially in the literature for STEM teacher education and the practice of teacher preparation, this is not the case (Jamieson-
Proctor, Finger, & Albion, 2010). Given the critical need for both high quality STEM education and 21st Century skills, this is a timely and significant research focus.

**Limitations and Delimitations of the Study**

This study is delimited to preservice science teachers enrolled in coursework at the research site; findings are not intended to be representative of all preservice science teachers outside of the context of the case. The focus of this study is on factors that influence the development of TPACK in science education majors currently, enrolled at a medium-sized university in Queensland, Australia. This includes students of traditional and non-traditional ages enrolled in face-to-face, blended, and online courses. The study examines only secondary preservice teachers who will teach science and does not include elementary teachers who are trained to teach in multiple content areas.

Given that the essence of the research question is to understand what factors shape the development of TPACK in preservice science teacher candidates within this specific context, it was determined that the clearest indication of knowledge sources would be that which participants cite, as opposed to what the researcher identifies from a more etic perspective. Whereas document analysis (e.g., syllabi, assignment guides, courses of study), observational field notes, or interviews with faculty and administrators may uncover elements of TPACK that are present in the program, the true objective of this study is to elucidate what experiences are actually shaping TPACK development in participants. This necessitates a focus on participant-identified experiences and values; it does not call for the quantification of TPACK-related experiences as identified by the researcher. For example, while such analyses may identify an equal number of instances
throughout the program wherein TPACK and its components are addressed, an examination of data from participants (i.e., interviews and survey responses) yielded only those instances that were recalled and reported as meaningfully influencing the participants, whether positively or negatively. As the intent of this study is to understand those experiences that are actually impacting TPACK development, any TPACK-related experiences that are not recalled, reported or valued as memorable to the participants, fall outside the scope of this study.

The greatest limitation of this study is the sample size of 12 participants. Conclusions drawn refer only to the participants of this study. Interviews and questionnaires yield self-reported data and include participant bias to some degree.

**Definition of Terms**

The following terms and definitions are offered to clarify key constructs and how they are operationalized within the context of this study:

*Preservice teachers or teacher candidates* are individuals enrolled in a formal teacher preparation program. They are completing coursework and experiences at the university level to prepare them for a teaching career in PK-12. This study focuses specifically on preservice secondary science teachers (i.e., teacher candidates who are preparing for a career teaching science in grades 7-12).

*Technology*, as operationalized within the context of this study, refers to emerging material technologies. As noted in chapter two, there exist some inconsistencies across the TPACK literature in regard to the operationalization of ‘technology’. To clarify, the focus of this study was on material technologies (i.e., tools or tool sets, such as software
and hardware). This definition excludes soft technologies (i.e., processes, methods, such as programmed instruction). Transparent technologies (i.e., those that are ubiquitous enough to be considered commonplace, such as dry erase boards or books) are also excluded. Emerging technologies (e.g., digital devices and applications) are included in the construct of ‘technology’ as operationalized in this study, while soft and transparent technologies are treated as facets of pedagogy. Related knowledge types are explained in detail in chapter two.

Of particular interest to this study are TPACK-related self-efficacy, values, beliefs and knowledge of preservice teachers. These constructs are all tightly intertwined and have a significant influence on both the development of teacher knowledge and practice.

Self-efficacy refers to beliefs about one’s own capabilities to plan and implement action resulting in success (Bandura, 1997).

Values, as operationalized in this study, are strong beliefs about worth. Values are not typically bound by context. Values can be both espoused (i.e., articulated) and/or enacted (i.e., implemented). Espoused values are discussed in this study as strong beliefs about worth that were identified by participants. Enacted values are operationalized as such beliefs that were applied or demonstrated in practice or in articulating specific plans for practice.

Beliefs have been referenced in this study as somewhat synonymous with personal opinion. They are viewed as ‘personal knowledge’ and are presented as such by participants. Beliefs can, but are not necessarily, based on evidence. They are developed from experience, organized into systems, and are bound by emotion (Gess-Newsome,
While beliefs may not carry the same requisite empiricism as knowledge, they are significantly entwined with an individual’s sense of ‘knowing’.

Knowledge is discussed in the current study as “evidential, dynamic, emotionally-neutral, internally structured, and develop(ed) with age and experience” (Gess-Newsome, 1999a, p. 55).

The distinction between belief and knowledge has been fuzzy at best in research. Philipp (2007) explains that “what is knowledge for one person may be belief for another, depending upon whether one holds the conception as beyond question” (p. 259). Southerland, Sinatra and Matthews (2001) note that...

it has not been shown that knowledge and beliefs have differential justifications…or that (students’) knowledge and beliefs clearly have different effects on the learning process. It remains for educational psychologists to demonstrate whether the theoretical distinctions between the constructs have any psychological reality. (p. 348).

Kagan (1992) cites consistent findings across numerous empirical studies that teachers’ beliefs typically parallel their approaches to practice and that this relationship persists across varying subjects and grade levels. As Etmer (2005) notes, “the knowledge base of teaching consists of few, if any, indisputable ‘truths’” (p.26); Kagan (1992), therefore, suggests “most of a teacher’s professional knowledge can be regarded more accurately as a belief” (p. 73). While beliefs and knowledge are discussed based on the aforementioned differences in evidence and emotion in this study, teacher beliefs, for all practical intents and purposes, can be viewed as tantamount to teacher knowledge. The significance of the
relationship between beliefs and knowledge is discussed along with relevant findings in chapter five.

**Contextual terminology differences.**

While the current study has been written for a U.S. audience, as the researcher has conducted the research in partial fulfillment of the requirements for a Ph.D. program in the United States, in an effort to maximize comprehension across contexts, the following explanations are offered to illuminate differences between U.S. and Australian terminology.

*Technology*, as operationally defined above, is referenced in the Australian context as *ICT*. While ICT is short for ‘information communication technology’, in the context of education, ICT encompasses both material and emerging technologies.

*Student*, in the context of U.S. teacher education, refers to individuals studying in preschool through grade twelve, while *candidate* is used in reference to an individual studying at the university level. In Australia, the term *student* is used to reference an individual studying at any level.

*Instructor* or *faculty* refers to all individuals teaching at the university in the U.S. The Australian equivalent is *academic staff*, as the term *instructor* is reserved for reference to a Pre-12 teacher. More specifically, there are terms that indicate various roles of academics in higher education. In the U.S., part-time academics are referred to as *adjunct* faculty, while in Australia they are *casual* faculty. While there are varied ranks of full-time faculty (e.g., instructor, assistant professor, associate professor, full professor) in the U.S. as well as Australia (e.g., associate lecturer, lecturer, senior lecturer, associate
professor, professor), these are typically not specifically identified in casual reference. In the U.S. academics are all often referenced as either instructor or faculty member. In Australia, however, academic staff are referenced casually by role as either tutor or lecturer (where lecturer is a catch-all term for anyone teaching a lecture course and tutor is in reference to individuals teaching a tutorial).

While the term university (often abbreviated as uni in Australia) has the same meaning in both a U.S. and Australian context, informally, the term college may be used interchangeably in the U.S., as the term uni is used in Australia. In an Australian context, the term college refers to on-campus housing areas, or what would be called residence halls or dormitories (i.e., dorms) in the U.S.

College in a U.S. context (e.g., College of Education) is the equivalent term for faculty in Australia (e.g., Faculty of Education). Both contexts may also use the term school within a university setting (e.g., School of Education).

Program, in a U.S. context, includes all classes and requirements for credential attainment. The equivalent Australian term for this is course.

Semester refers to an academic term in the U.S., while the Australian equivalent is session (e.g., Fall, Spring and Summer semester/session).

Course refers to an individual topic that is taught over the course of one term in a U.S. context. In Australia, the equivalent term is unit.

Within the teacher preparation program, both U.S. and Australian contexts include experienced-based learning opportunities in which preservice teachers spend time
teaching under supervision in schools. In the U.S., this is most often called student teaching. In Australia, this is typically referred to as prac, short for practical experience.

Grades, the evaluative indicators in a U.S. context, are called marks in Australia. Points are often assigned and tallied to calculate grades, while marks are assigned and tallied to assign marks. The act of evaluating assessments is called grading in the U.S., and marking in Australia. The term grade in the U.S. is also used in reference to the number of years a student has been in school, while the word year is used in Australia (e.g., ‘5th grade’ in the U.S. is ‘Year 5’ in Australia).

Organization of the Study

This study is arranged into five chapters. The first has provided an introduction to the study, including an explanation of the problem and purpose. The research questions have been outlined, and the significance of the study to various stakeholders has been detailed along with its limitations and delimitations. Key terms have been operationally defined, and the organization of the study is presented here. Chapter two provides a review of the literature on TPACK. It addresses each conceptual component as well as the issue of ambiguity of boundaries between these components along with varying perspectives on the framework and gaps in the literature. Chapter three details the methodology employed in the study; it includes a rationale for the selected case, a detailed description of the context, information about the population and sample, data collection and analysis procedures and facets related to credibility. Chapter four presents the findings of this study by research question, including visual representations of the
data, and chapter five discusses key findings and implications along with recommendations for future research and a conclusion.
Chapter 2: Literature Review

Technological pedagogical content knowledge (TPCK or TPACK) is built on the foundation of Shulman’s (1986) pedagogical content knowledge (PCK) framework. This framework, detailed further in the following sections, defines knowledge of subject matter (content) and knowledge of instructional considerations and strategies (pedagogy) and describes how these may interact or combine to form a unique form of knowledge (pedagogical content knowledge) (Shulman, 1986). While utilization of technology had accompanied previous discussions of PCK (Angeli & Valanides, 2005; Margerum-Leys & Marx, 2004; Niess, 2005; Pierson, 2001; Wallace, 2004), and the term technological pedagogical content knowledge was introduced by Koehler and Mishra in 2005 (Koehler & Mishra, 2005a), it was their seminal article published the following year that presents a complete model of TPCK, as it was termed and referenced in subsequent literature (Mishra & Koehler, 2006). This framework proposes technological knowledge as a fourth component to extend PCK, articulating technological knowledge (TK), content knowledge (CK) and pedagogical knowledge (PK) as foundational facets; the model is further anatomized into paired components of pedagogical content knowledge (PCK), technological content knowledge (TCK) and technological pedagogical knowledge (TPK) and presented technological pedagogical content knowledge (TPCK) as an extended conceptual framework for understanding the complex, situated knowledge necessary to effectively teach with technology (Mishra & Koehler, 2006). Originally termed TPCK (Mishra & Koehler, 2006), the abbreviation was changed in 2007 at a meeting of National Technology Leadership Institute to TPACK (pronounced “tee-pack”) in order to
create a more memorable acronym, emphasize the three distinct components of technology, pedagogy and content, and to reflect the synergy of these three facets (referenced as the “Total PACKage”) (Thompson & Mishra, 2007).

The TPACK Framework

TPACK is a conceptual framework of a body of knowledge from which teachers draw upon to influence practice (Doering, Scharber, Miller, & Veletsianos, 2009). The framework consists of individual components, but is also concerned with transactional relationships among these components (Mishra & Koehler, 2006).

Conceptual components.

The TPACK framework consists of individual components (TK, PK, CK), dual components (PCK, TCK, TPK), and the synergetic TPACK.

Technological knowledge (TK).

Technological knowledge, as defined in the context of TPACK, extends beyond basic computer literacy. Based upon the fluency of information technology ("FITness") construct, as defined by the Committee on Information Technology Literacy of the National Research Council (NRC, 1999), TK encompasses the knowledge and skills required to effectively learn, master, and utilize various technologies for information processing, communication, and problem-solving (Harris, Mishra, & Koehler, 2007). As technology is ever evolving, so too is technological knowledge. TK is considered developmental, a type of knowledge that is generated and adapted over time through new and varying interactions and experiences (Harris, Mishra, & Koehler, 2009; Koehler, & Mishra, 2008; Harris, 2008).
**Content knowledge (CK).**

Content knowledge is knowledge of the subject matter. This is subject-specific; for example, science content is different from mathematics content. Content knowledge is the body of knowledge from the field. Subject matter experts have a wealth of content knowledge, but may lack the pedagogical or pedagogical content knowledge to effectively teach what they know. Shulman (1986) notes that concepts, theories, organizational frameworks, and field-specific practices for developing knowledge all fall under the umbrella of content knowledge. Knowledge and approaches to inquiry are field-specific, and content knowledge is an important foundation for teachers to develop (Koehler & Mishra, 2008).

**Pedagogical knowledge (PK).**

Pedagogical knowledge comprises a general conception of how students learn. This includes knowledge of social, cognitive and developmental learning theory and an understanding of educational goals, values, strategies and intents. PK involves strategies and methods for classroom management, lesson planning, assessment and evaluation as well as comprehension of how learners construct knowledge and develop dispositions toward learning (Harris et al., 2009). Morine-Dershimer and Kent (1999) delineate three types of pedagogical knowledge, including general pedagogical knowledge, personal pedagogical knowledge and context specific pedagogical knowledge. General PK includes knowledge of strategies for instruction, models of instruction, classroom management, classroom organization and classroom communication and discourse. Personal PK is informed by personal beliefs and perceptions as well as practical
experience. Both general and personal PK, when combined with reflection, yield context specific pedagogical knowledge (Morine-Dershimer & Kent, 1999).

**Pedagogical content knowledge (PCK).**

Pedagogical content knowledge (PCK) refers to the understanding of how certain subject matter can be optimally organized and communicated for diverse learners; PCK, as Shulman (1987) asserts, is a distinguishing characteristic between educators in particular content areas and content experts (Shulman, 1987). For example, scientists may possess a wealth of content knowledge but lack the pedagogical content knowledge required to be effective science educators. PCK was originally explained by Shulman to include two components: knowledge of ‘representations’, which include instructional strategies, explanations, representations and demonstrations that educators use to help present and clarify content for learners; and knowledge of students’ ‘learning difficulties’, which encompasses misconception, disinterest or any other barriers to learning which may have resulted from prior experience with a particular topic and how to appropriately address correcting misconception and scaffold further learning of this subject matter (Shulman, 1996, 1997).

Shulman’s model of PCK has been utilized and developed throughout the literature since its initial conception. Later, Grossman (1990) further expounded on the model of PCK by describing two additional components to be added to those outlined in Shulman’s original model; these two constructs include a rationale for teaching specific content and curricular knowledge (i.e., what constructs and skills should be learned, and in what order and why). Magnusson, Krajcik, and Borko (1999) formulated a set of five
PCK components based on these categories in their own research, including a teacher’s orientation (i.e., beliefs, goals, and approaches) toward teaching in their content area, knowledge of curriculum, knowledge of assessment (i.e., what content knowledge will be assessed, how and why?), knowledge of students’ understanding of the content, and knowledge of instructional strategies. McCaughtry (2005) contends that while Shulman’s (1987) model of PCK is a valuable construct for understanding the integration of teachers’ knowledge of subject matter, pedagogy, curriculum, and learning processes as a unique form of knowledge in and of itself, it neglects related knowledge types upon which teachers draw to inform their teaching. Namely, McCaughtry (2005) emphasizes that emotional and social knowledge of students is combined with the knowledge types referenced by Shulman and constitute a noteworthy aspect of PCK.

Morine-Dershimer and Kent (1999) offer three assertions on pedagogical content knowledge: knowledge of educational ends, goals, purposes, and values is inextricable from knowledge of assessment procedures and evaluation methods (referenced together as assessment/objectives knowledge here for brevity); curriculum knowledge is informed by this assessment/objectives knowledge as well as content knowledge; and pedagogical knowledge is informed by both assessment/objectives knowledge and knowledge of learners and learning. All of these, in combination with knowledge of educational context, are enveloped by pedagogical content knowledge (Morine-Dershimer & Kent, 1999).

In further organizing PCK, Veal and MaKinster (1999) classify levels of PCK in a hierarchical taxonomy. This includes general PCK, which is pedagogical knowledge
related to the general content area (e.g., science), domain specific PCK, which is pedagogy related to a particular subject within the content area (e.g., biology), and topic specific PCK, which includes knowledge pertinent to teaching the specific concepts within the content area (e.g., cellular mitosis).

**Technological content knowledge (TCK).**

Technological content knowledge (TCK) is an understanding of which technologies suitably align with particular fields or disciplines. This is not necessarily specific to education and does not involve an instructional aspect; rather, TCK is concerned with matching of technologies with content. This includes the knowledge that the use of technology may either impede or enhance the representation of content (Harris et al., 2009; Mishra & Koehler, 2006).

**Technological pedagogical knowledge (TPK).**

Technological pedagogical knowledge refers to an understanding of the affordances and limitations of technologies as used for teaching and learning. This includes knowing which technologies are in suitable alignment with teaching and learning strategies at developmentally- and age-appropriate levels as well as which technologies lend themselves best to particular educational contexts (Harris et al., 2009). Harris et al. (2009) note that the ability to think creatively about technology applications for teaching and learning is a particularly important aspect of TPK in that most technology is not specifically intended for educational purposes. Thus, the understanding and ability to align context-applicable pedagogical approaches (i.e., pedagogical methods and strategies for learning) with effective technologies for meeting educational objectives
is critical. Technological pedagogical knowledge entails more than the application of technology for learning, but a “forward-looking, creative, and open-minded seeking of technological application, not for its own sake, but for the sake of advancing student learning and understanding” (Harris et al., 2009, p. 399).

**Technological pedagogical content knowledge (TPACK).**

Technological pedagogical content knowledge (TPACK) necessitates all previously addressed forms of knowledge and, in the explanation of the framework offered by Harris et al. (2009), constitutes a form of knowledge that is more than a simple composite of its elements. TPACK refers to the knowledge necessary to thoughtfully adapt and align available technology with developmentally and contextually appropriate approaches to instruction; it is the knowledge necessary to teach subject matter with appropriate technologies in a deliberate and effective manner.

Such proficiency requires the ability to navigate intricate systems of knowledge (Shulman, 1986, 1987). Teaching is a highly complex skill, which requires comprehension of various knowledge types and constant calibration within a dynamic environment (Spiro, Feltovich, Jacobson, & Coulson, 1991). Instructional contexts vary widely across a multitude of factors tied to characteristics of learners and attributes of the learning environment, including influencing factors (e.g., culture, policies), which shape the experience from outside of the immediate context. Technology is evolves, and new knowledge is generated and revised within content areas, making TPACK a highly dynamic framework (Cox & Graham, 2009). The notion of teaching with technology is classified by Koehler and Mishra (2008) as a ‘wicked problem’, in reference to Rittel and
Webber’s (1973) explanation of the term. Such scenarios contain multidimensional, interconnected, and ever-evolving variables (Rittel & Webber, 1973). Such ‘problems’ necessitate flexibility, inventiveness in the conception, implementation and adaptation of instruction as teachers draw from field-specific content knowledge, insights on context, related learning theories, instructional approaches, and technologies. The effective employment of TPACK demands consideration of all aspects of the model in tandem, as they influence and interact with one another, not simply an examination of each segment in isolation (Koehler, Mishra, & Yahya, 2007; Mishra & Koehler, 2006).

TPACK is an emergent form of knowledge. The development of TPACK is an “additive, recursive, and expansive process, rather than a linear series of replacements of ‘old’ with ‘new’” (Harris, 2008, p. 269). Koehler and Mishra (2008) describe a ‘spiral-like’ development of TPACK, acknowledging that the inclusive definition of technology, which encompasses both analog and digital technologies, may lend itself to an approach in which development begins with more familiar forms of technology for integration and evolves to build the knowledge and skills necessary to integrate more advanced technologies. Particularly in preservice teacher preparation, this would occur simultaneously with the expansion of content knowledge and knowledge of pedagogy. As such, the nature of TPACK is greatly dynamic: the teacher, influenced by context, draws on knowledge for practice (Doering, Scharber, et al., 2009). Bull et al. (2007) describe the employment of TPACK as an iterative and organic process, constantly informed by fluctuating, contextual variables. They note that the ability to optimally balance the
multiple domains for successful instruction is a difficult skill to acquire (Bull et al., 2007).

**Ambiguity of boundaries.**

The fundamental explanations of these conceptual components seem fairly straightforward and are rather intuitive in their conception. The categorization of thought and action from authentic settings into this framework, however, is often problematic and may seem somewhat contrived due to a blurring of boundaries between these transactional components. Marks (1990) makes three observations regarding PCK, which have direct implications for the TPACK model’s ability to clearly differentiate between its constructs.

The first point is that any examples of a grouped component (e.g., pedagogical content knowledge) will always inherently contain evidence of each single component (e.g., pedagogical knowledge and content knowledge) as well. That is, it becomes difficult to distinguish between examples that demonstrate both pedagogical knowledge (PK) and content knowledge (CK) and examples of pedagogical content knowledge (PCK). Marks argues that resigning such examples to a category becomes a matter of focus (1990). The same concern holds true for aspects unique to TPACK. For instance, a teacher’s use of simulations to teach molecular activity during heat transference could potentially be categorized in five different ways, depending on one’s focus: as 1) technological knowledge, pedagogical knowledge, and content knowledge; 2) technological pedagogical knowledge and content knowledge; 3) technological knowledge and pedagogical content knowledge; 4) technological content knowledge and
pedagogical knowledge; and 5) technological pedagogical content knowledge. For researchers employing the TPACK framework, this necessitates a clearly articulated and consistent approach to delineation within the context of a study.

The second issue Marks (1990) notes of PCK is that because it is applied within the context of education, it becomes easy to impose an educational perspective on examples and observations which may not necessarily be expressed in those terms. For instance, if a science teacher is discussing relevant issues about a topic they happen to teach, it may be interpreted in pedagogical terms due to context even if they are not addressing the instruction of that topic. This clearly has the same implications within the context of the TPACK framework.

Marks’ (1990) final concern is that assertions made about teaching about specific subject matter can often be applicable across various content domains. As an example, a chemistry teacher might discuss an inquiry project in her class; the researcher might focus on this explanation as evidence of the teacher’s knowledge of inquiry as a pedagogical approach, thus labeling it pedagogical knowledge, or as evidence of the alignment of content with appropriate pedagogy strategies for the specific topic at hand (i.e., pedagogical content knowledge). This issue is relevant within the context of TPACK.

Similar concerns for ambiguity might be noted regarding technological knowledge as well. For instance, a teacher’s noted use of a teacher website to keep parents apprised of goals and activities in the classroom might be categorized as technological knowledge or as technological pedagogical knowledge, depending on the
perspective of the researcher. Gess-Newsome (1999b) cites the overlap of PCK components as a concern for establishing clearly delineable, unambiguous bounded categories to be used for research. While this lack of precision is a legitimate concern for consistency, all of these issues might be addressed by the use of clearly explained and deliberately applied coding techniques. Cox (2008) conducted a conceptual analysis of the components of the TPACK framework after encountering difficulties with these ambiguities in her own research. In her analysis, she offers bounded definitions of the components as she has defined them from the literature and through discourse with experts in the field. She offers examples of each along with a discussion of borderline cases (Cox, 2008).

Regardless of these issues surrounding specificity, Gess-Newsome (1999b) notes affordances of the PCK model (extended here to TPACK), for educational research. TPACK provides an analytical framework for the data collection and analysis of teacher cognition. In the same way that PCK acknowledges content knowledge as a crucial facet of teacher knowledge, TPACK highlights technological knowledge as essential for teaching. The TPACK framework advances an integrated perspective of teacher knowledge and practice (adapted from Gess-Newsome, 1999b).

**Varying perspectives.**

**The ‘T’ in TPACK.**

There are varying descriptions of the construct of technology within the framework of technological knowledge. In the *Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators*, Koehler and Mishra (2008) are clear in their
assertion that ‘technology’ is meant to be used in the broadest sense of the word. They intended to include all manmade tools, both analog and digital, created to facilitate the work of addressing problems, needs and desired achievements; clearly, this encompasses a expansive range of tools from pencils to calculators, microscopes to mobile phones, and much beyond and in between (Koehler & Mishra, 2008; Mishra & Koehler, 2006).

Further extending boundaries of the construct is the idea that the term may refer to one specific tool (e.g., interactive whiteboard) or a collection of tools (e.g., word-processing technology) (Koehler & Mishra, 2008). Within the discourse on educational communications and technology, the term comprises not only material technologies (i.e., tools and tool sets), but also soft technologies, or methods and procedures; for example, programmed instruction is considered an instructional technology (Graham, 2011).

Of course well-developed studies operationally define technology within the context of the research. Several researchers have taken advantage of the somewhat ambiguous nature of ‘technology’ as it is defined (or not) in the TPACK literature to specify their own variation of the framework. Examples include a focus on information communication technologies, termed ICT-TPACK (Angeli & Valanides, 2009) web technologies, labeled TPACK-W (Lee & Tsai, 2010) and the use of G-TPACK in reference to geospatial technologies (Doering, Scharber, et al., 2009).

Cox (2008) calls attention to the distinction of transparent vs. emerging technologies in an attempt to clarify and narrow the focus on technology within TPACK. Transparent technologies are identified as those, which may be typically ubiquitous in a learning environment (e.g., writing utensils, textbooks), while more modern (often
digital) tools are categorized as emerging technology (Cox, 2008). While this still leaves some room for debate as to what is ‘typical’ in the context of specific learning environments, this approach allows researchers to relegate focus on transparent technologies, which may not be of interest to their study, as part of PCK and focus instead on emerging technologies and their integration into instruction (Graham, 2011).

**Integrative vs. transformative views.**

There has been additional debate and variation across the literature regarding the integration and treatment of the technology piece of TPACK, yielding a various interpretations of the construct as a whole (Cox & Graham 2009; Graham, 2011; Niess 2011). Some argue that while Shulman’s PCK does not overtly address technology, its inclusion is implicit in the conceptualization of pedagogical content knowledge, as technology may be used (as a tool, set of tools or method) for organizing, formatting, presenting and assessing content (Angeli & Valanides, 2009). Within this perspective, the ‘T’ in TPCK may be an unnecessary isolation of a pedagogical consideration. Certainly, Shulman (1986) did call for the appropriate selection and use of technologies for the representation of content in teaching as part of curricular knowledge. Koehler and Mishra (2008) contend that the role of technology extends beyond this narrow purpose (i.e., representation of content) and as such, requires specific attention in the framework of critical teacher knowledge. While Cox and Graham (2009) maintain that technology was an intended inclusion within Shulman’s PCK model, they distinguish TPACK as suitable prospect for highlighting teachers’ understanding and approach to the integration of emerging technologies into their instruction. They suggest that once these emerging
technologies become transparent (i.e., its use is widely accepted or commonplace in the
field of education), they should once again fall into the realm of PCK, portraying TPACK
as a ‘sliding’ framework of sorts (Cox & Graham, 2009).

Among those who distinguish technological knowledge as a critical component is
further divergence into integrative and transformative perspectives of the model. Gess-
Gess-Newsome (2002) describes these two perspectives as opposite endpoints of a
continuum of views on PCK. Grossman portrays PCK as a transformative concept
consisting of more than just the two domains of content and pedagogy, but including
knowledge and beliefs about context as well; Abell (2008) advocates a more
transformative view of PCK, asserting that, as applied by preservice and in-service
teachers, it is more dynamic and complex than the combination of its components. Other
researchers question Shulman’s assertion that PCK is a transformation of the
componential forms of knowledge into a new form of knowledge that exists separately
from these bases (Marks, 1990). Instead, these researchers propose that PCK is the
integration of these individual knowledge bases during the act of teaching (Gess-
Newsome, 1999b).

Similarly varying perspectives appear in the literature on TPACK. An integrative
understanding of the framework involves individual knowledge types (TK, PK, CK) that
can be paired (PCK, TCK, TPK) or combined in total as TPACK, a form of knowledge
that is in essence the sum of its parts (Angeli & Valanides, 2009). A transformative
perspective posits that each knowledge type in the TPACK model is a distinctly unique,
synthesized form of knowledge (i.e., the development of knowledge types such as TK,
PK and CK does not inherently equate to an increase in TPACK (Angeli & Valanides, 2009; Gess-Newsome, 1999b). Some researchers have focused on individual components and used them to support an inference of TPACK (Doering, Scharber, et al., 2009; Guzey & Roehrig, 2009). Others utilize both the integrative and transformative perspectives to investigate the presence of TPACK (Mouza & Wong, 2009). Graham (2011) notes that TPACK is often reduced to a term synonymous with technology integration, employed in empirical research without acknowledgement of the other components of the model. These varying perspectives on TPACK directly mirror such inconsistencies in the PCK literature, as some researchers question whether PCK is a new form of knowledge in and of itself or simply the combination of pedagogical and content knowledge types (Marks, 1990).

**Self-Efficacy**

Self-efficacy refers to beliefs one holds about their ability to achieve desired outcomes (Bandura, 1997). Zimmerman (2000) outlines key properties of self-efficacy beliefs: they are ‘multidimensional’ and tied to a specific domain of functioning (e.g., one may have a high perception of self-efficacy for preparing a cheese sandwich but hold low self-efficacy beliefs for preparing a soufflé). They are ‘contextual’ (e.g., one's perceived capability for success for a task may decrease as stressors increase). Self-efficacy beliefs are ‘focused on mastery’ rather than norm-referenced criteria (i.e., the belief of one's likelihood to achieve a desired outcome given a set of parameters, not a belief about how one's performance will compare to others'). Self-efficacy beliefs are about potential to
achieve at ‘future’ tasks (i.e., one's belief about their capability to accomplish a task prior to undertaking it). Zimmerman (2000) notes that “this antecedent property positions self-efficacy judgments to play a causal role in academic motivation” (p. 84).

Bandura (1977) notes that beliefs about one's ability to achieve a given outcome influence decision-making, impact the amount of effort (i.e., persistence) one exerts toward that aim, and affect the emotional reaction to success or a lack thereof. That is, the more confidence one has in their ability to achieve a successful outcome, the more likely they are to attempt it and cope with and persist through adversities in their attempts to achieve it, while lower levels of perceived self-efficacy lead to avoidance. A person's sense of self-efficacy is informed by prior experience. Bandura (1997) identified mastery experiences as the most impactful on self-efficacy and, as a result, behavioral choices influenced by self-efficacy. He notes that a teacher's belief in his/her capabilities will guide their decisions regarding pedagogy.

While TPACK is necessary for planning effective technology-facilitated instruction, confidence in drawing upon TPACK to implement such instruction is also required (Ertmer & Ottenbreit-Leftwich, 2010). Higher levels of TPACK self-efficacy contributes to greater willingness to utilize technology for teaching (Sahin, 2008). Conversely, lower TPACK-related self-efficacy has been shown to leave teachers less inclined to integrate technology into the curriculum (Bednar & Sweeter, 2005). Abbitt (2011) notes that

Bandura’s theory of self-efficacy would suggest that increasing teacher knowledge would lead to increased self-efficacy beliefs and, potentially, to an
increase in technology use in the classroom as well as an increased likelihood that this technology use will be based on knowledge of pedagogy and content. (p. 137).

The Teaching Apprenticeship

Lortie (1975) coined the term *apprenticeship of observation*, describing the notion that preservice teachers enter their professional preparation programs with over a decade-long history of observing and evaluating professionals in their chosen field (i.e., their teachers). Lortie further explains this apprenticeship:

There are ways in which being a student is like serving an apprenticeship in teaching; students have protracted face-to-face and consequential interactions with established teachers…the student learns to “take the role” of the classroom teacher, to engage in at least enough empathy to anticipate the teacher’s probable reaction to his behavior. This requires that the student project himself into the teacher’s position and imagine how he feels about various student actions. (Lortie, 1975, pp. 61–62)

Certainly, the long history of prior experience as a student observing teachers contributes to the selection of teaching as a career path and the conception of what it means to teach. Watt et al. (2012) sampled teachers from Australia and the U.S., along with Germany and Norway, to investigate motivations for teaching and found that positive prior teaching and learning experiences to be among the highest rated motivations to pursue a teaching career across samples from all contexts. In fact, this motivator was highest for preservice
teachers in the U.S. and Australia. They reference the notion of Lortie’s apprenticeship of observation in their own work, explaining that

Because almost every individual has been a student, effective (and ineffective) teachers can provide powerful role models, as well as the opportunity for vicarious personal judgments concerning one’s own teaching-related abilities. Other professions may not be so readily visible to the public, who may not feel that they have a good idea of what it is that other professions involve; consequently we would not expect the influence of this motivational factor to apply in the same way to individuals’ choices of other professions. (Watt et al., 2012, p. 804)

This highlights the uniqueness of teaching as an apprenticeship in that it is the only profession in which all citizens (in most countries) have observed the profession for years.

Personal beliefs about the nature of teaching and learning are cultivated from such experiences, which serve as a frame of reference as preservice and beginning teachers develop their professional identities (Flores & Day, 2006). In additional to its impact on the determination of teaching as a career and professional identity, this apprenticeship experience influences the development of a career path (Rinke, Mawhinney, & Park, 2014). Not only do perceptions of the teacher influence preservice teachers’ beliefs and intentions for their practice, but experiences from the student perspective during this apprenticeship period may impact beliefs and practice as well, as preservice and
beginning teachers may project their own experiences onto those of their students or even their students’ parents (Greenwalt, 2014).

While the dramatic impact of the preservice teacher’s typically conservative prior experiences with the profession often leads teacher educators to consider it a hurdle to overcome or neutralized, it may, when addressed directly and critiqued through the lens of theory, become a useful tool in the development of professional knowledge (Darling-Hammond, 2006; Grossman, 1991).

Gaps in the Literature

The *Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators* calls for “schools, colleges, and departments of education to engage their professors, cooperating teachers, and teacher-students in constructive exploration of and dialogue about the flow of technological pedagogical content knowledge in facilitating high-quality, effective instruction for all learners” (Brown & Cato, 2008, p. viii). Utilization of the TPACK framework provides opportunities for connecting educational research and practice (Mishra & Koehler, 2006). The TPACK framework can be seen as both a representation of the knowledge teachers must have in order to effectively use technology for teaching their content or as a framework for analyzing how innovative strategies for teaching with technology emerge (Abbitt, 2011).

There is a need for research to inform teacher educators in the development of TPACK in preparation programs (Polly & Brantley-Dias, 2009). The TPACK framework may be employed both to assess how experiences in teacher preparation programs influence the development of preservice teachers’ related knowledge, attitudes, and
cognitive processes as well as to measure outcomes that lead to effective technology-enhanced teaching practices (Abbitt, 2011).

While some studies have focused on preservice teachers, Cox (2008) notes that most are wholly descriptive and are either too specific to be replicated in another context or do not provide sufficient detail to be of much value. Abbitt (2011) notes the need for researchers to utilize multiple approaches to collect and analyze data in order to provide context sensitivity needed to thoroughly investigate specific cases as well as yield enough information to allow for cross-disciplinary comparisons and longitudinal studies. Abbitt suggests both quantitative and qualitative approaches to employing the framework in research on teacher preparation using the TPACK framework (Abbitt, 2011).

Studies that examine TPACK as a body of knowledge to be used to assist in the instruction of specific content areas are lacking (Cox & Graham 2009; Niess 2011). To fully assess TPACK as the framework is intended (i.e., more than technology integration knowledge) (Graham, 2011), studies that explore the application and development of TPACK within a specific content domain are essential. Mishra and Koehler (2006) cautioned against the application of TPACK in a context-neutral approach, explaining that devoid of a context-informed development of technological pedagogical knowledge and technological content knowledge, a natural overemphasis on technology would result. Other researchers concur, maintaining that understanding relationships between technology, pedagogy, and content is a requisite for effective teaching (Hughes, 2005; Lundeberg, Bergland, Klyczek, & Hoffman, 2003). The TPACK framework is intended to portray a balanced model in which all components are necessary for effective teaching,
not simply a focus on technology use (Mishra & Koehler, 2006). Loveless, DeVoogd and Bohlin (2001) clarify that the TPACK framework does not propose a technocentric automation of learning, but rather a conscious and deliberate approach to integrating appropriate technologies into the thoughtful teaching of content.

Measurement instruments that address TPACK within a specific content domain, including the most common format, self-assessments, are scarce or underdeveloped; further efforts in the development of tools and methods for studying content domain-specific TPACK are needed (Voogt et al., 2012). There exists a lack of attention to precisely defining the components (e.g., technological content knowledge, technological pedagogical knowledge), which need additional clarifying and empirical examination in the literature (Cox, 2008). Voogt et al. (2009) identify the need for research on teachers beliefs as they relate to practical knowledge and TPACK.

Creswell (2002) outlines suitable strategies for using literature in a qualitative study, noting that in qualitative research designs, it is common to present the bulk of the literature at the end of the study alongside findings. The current chapter synthesized the literature that informed the design of this study. Additional literature is used to provide a rationale for the selected case and description of the context in the following chapter. Chapter 5 will draw upon additional literature to interpret and situate findings; this is indicative of the inductive nature of the qualitative study. This review of the literature reflects the need to define TPACK thoroughly within the context of a study that explores all components individually as well as their interactions with one another as relevant to a specific content domain. Such a study, designed to identify sources of TPACK-related
knowledge and self-efficacy (both external to and within the teacher education context) and inform the development of content domain-specific TPACK among preservice teachers, could prove a valuable addition to the literature.
Chapter 3: Methodology

Rationale for Selected Case

Glesne (1999) cites the need to provide a well thought-out rationale for the selection of a data collection site. This case has been selected based on a number of considerations, including the nature of TPACK development within the university curriculum, the opportunity to collaborate with experts in the field, and the timeliness of the study in relation to a relevant, recently implemented national program.

Beck and Wynn (1998) describe a continuum of technology integration in teacher preparation programs in which, on one end, technology is integrated into every aspect of the program (i.e., across methods courses) and on the other end, a program which reserves instructional technology integration strategies to a designated technology course. Currently, many institutions in the U.S. offer one or more isolated technology courses for preservice teachers which focus on technology integration strategies, while faculty who teach methods courses may or may not elect to integrate technology and/or discuss surrounding issues related to TPACK. This case was originally selected because the program in this study was initially thought to fall further to the other end of the continuum, in which technology integration is addressed along with pedagogy and content knowledge throughout the curriculum (Lock & Redmond, 2010). Niess (2005) asserts that, while there are a great many supporters of this approach, there is a lack of research examining how this approach supports the development of TPACK.

As data collection for the study was supported through the East Asia and Pacific Summer Institutes (EAPSI) fellowship, sponsored jointly by the National Science
Foundation (NSF) and Australian Academy of Science (AAS), it required identification and nomination of a host researcher, or point of contact at the research site. The host, in this instance, is a leader in TPACK research and had recently led the development of an approach to measuring the construct among preservice teachers as part of the national Teaching Teachers for the Future (TTF) project in Australia (Finger, Jamieson-Proctor, & Albion, 2010; Finger et al., 2012; Jamieson-Proctor et al., 2010; Jamieson-Proctor et al., 2012). TTF was established to create systematic change in ICT proficiency of K-12 teachers and to develop a national support network for teacher educators. The project centers on the TPACK model. A framework was developed for preservice teachers to assess their ICT proficiency against Australia’s National Professional Standards for Teachers. Digital learning and curriculum resource packages were produced to utilize in preservice teacher preparation to enhance ICT integration throughout English, mathematics, science and history in the Australian Curriculum (Australian Government Department of Education, n.d.). This national effort to address the development of TPACK in teacher preparation programs is well deserving of our attention as the Obama administration has declared transforming education in the U.S. an ‘urgent priority’ (U.S. Department of Education, 2010).

While every effort was made to gather data from an Australian teacher preparation program because of this relevant and novel framework, the reality is that the TTF resources have not been widely adopted. While the standards for initial teacher preparation indicate a focus on ICT, the manner in which this is addressed is at the discretion of the institution, and this context, while there were several faculty
participating in and evaluating the TTF project, did not utilize the digital packages that support ICT integration for specific subjects. While this was a national collaborative effort, involving all 39 Australian teacher education institutions, adoption of the digital resources was not mandated. As results later indicated, the use of ICTs was often a box to be ticked, however superficially. The structure of the teacher preparation at the research site is highly similar to many found in the U.S. That is, there is one ICT-specific course in a program designed to otherwise address content and pedagogy. The fact that this case did not end up being a novel approach to teacher preparation does not preclude consequential findings. In fact, the pervasiveness of this teacher preparation model across international contexts demonstrates a global scope of impact for mapping and understanding the development of TPACK within similarly structured programs. As such, this research is an important stride toward the understanding and systematic improvement of teacher preparation.

The research, approved by the Ohio University Institutional Review Board (Appendix A) employs a case study approach to gather and analyze data from administrators, teacher education faculty, and preservice teacher candidates on the development of TPACK in the science teacher preparation program at a medium-sized university in Queensland, Australia. This approach utilizes interviews, data from a TPACK survey instrument and limited document analysis in order to yield a detailed and triangulated understanding of the research focus. Merriam notes that, “case study has proven particularly useful for studying educational innovations, for evaluating programs, and for informing policy” (Merriam, 1998, p. 41). The intent is to describe the nature of
preservice science teachers’ TPACK and identify key factors that shape this
development. The case selected represents a typical approach to teacher preparation in
both Australia and the U.S., yielding great potential for transferability of findings and
implications.

Description of Context

The Digital Education Revolution (DER), established in 2009, was a government-
funded reform aimed to prepare Australian students for successful existence and
participation in a digital world (Department of Education, Employment and Workplace
Relations, 2009). The plan called for the achievement of one computer to every
Australian student in years 9 through 12 school by the year 2011 (Rosman, White, &
Hoad, 2008). The implementation of this plan focused mainly on acquisition of
technologies and infrastructure, as the National Broadband Network was also being
developed at the time, though supplementary online curriculum was also developed
(Romeo, Lloyd, & Downes, 2012). The TTF grew out of these initiatives as an emphasis
on the effective use of ICTs for teaching and learning has grown in Australia.

Curricular decisions had historically been state- and territory-directed in
Australia until the Educational Goals for Young Australians (Ministerial Council on
Education, Employment Training and Youth Affairs, 2008) called for the development of
a national curriculum. This national curriculum includes the use of ICTs as a general
capability, integrating them throughout the curricula for core subject areas initially
developed. The TTF project was developed in response to these changes in expectations
and standards and was aimed at aligning teacher preparation programs with the new standards for ICT use (Romeo et al., 2012).

Additional changes were in store for Australian teacher preparation programs in the form of new professional standards. The Australian Institute for Teaching and School Leadership (AITSL) was founded in 2010 and nationalized the accreditation of such programs. The National Professional Standards for Teachers include seven standards, with multiple focus areas embedded in each, focusing on three domains of teaching, including professional knowledge, professional practice and professional engagement. These standards outline proficiencies at various career stages, including ‘graduate’, ‘proficient’, ‘highly accomplished’ and ‘lead’. Not only do these standards guide accreditation of programs, but also as of 2016, preservice teachers graduating from accredited Australian programs must demonstrate that they meet the criteria for graduate teachers in order to gain certification (Australian Institute for Teaching and School Leadership, n.d.).

The Australian Curriculum, Assessment and Reporting Authority (ACARA) outlines general capabilities in the Australian curriculum and includes a substantial emphasis on ICT capabilities (2003). These capabilities include knowledge, skills, behaviors and dispositions relating to ICT. The scope and nature of ICT capabilities are intended to be fluid, as technology continuously develops. ICTs are to be integrated throughout all areas of the curriculum and ICT capabilities, but are also the explicit focus of the Digital Technologies curriculum. ACARA (2003) notes that
Students develop capability in using ICT for tasks associated with information access and management, information creation and presentation, problem solving, decision making, communication, creative expression, and empirical reasoning. This includes conducting research, creating multimedia information products, analysing data, designing solutions to problems, controlling processes and devices, and supporting computation while working independently and in collaboration with others. Students develop knowledge, skills and dispositions around ICT and its use, and the ability to transfer these across environments and applications. (p. 49)

ICT capabilities are organized along a continuum with benchmarks set every two years from Foundation (i.e., Kindergarten) through Year 10 (the last compulsory year of secondary school). These include five elements, each with nested focus areas (listed in parentheses): 1) applying social and ethical protocols and practices (recognize intellectual property; apply digital information security practices; apply personal security protocols; identify the impacts of ICT in society); 2) investigating with ICT (define and plan information searches; locate, generate and access data and information; select and evaluate data and information); 3) creating with ICT (generate ideas, plans and processes; generate solutions to challenges and learning area tasks); 4) communicating with ICT (collaborate, share and exchange; understand computer mediated communications); 5) managing and operating ICT (select and use hardware and software; understand ICT systems; manage digital data) (ACARA, 2003, pp. 53-54).
Preservice secondary science teacher candidates at a medium-sized university in Queensland, Australia are the population of interest for this study. At the time of the study, over 27,000 students were enrolled at the university, with 18.8% enrolled across ten degree programs in the college in which this study took place. The participants are enrolled in one of two programs in the School of Teacher Education and Early Childhood that prepare individuals to teach secondary (i.e., grades 7 through 12 in Australia) science. The case is bound in this context, described herein.

**Program structure.**

There are two programs offered via the School of Teacher Education and Early Childhood, both of which prepare preservice teacher candidates for licensure in secondary education.

**Undergraduate program.**

The undergraduate program is a 4-year, full-time (or part-time equivalent) curriculum that results in a Bachelor of Education. The program may be completed on-campus or online. Candidates must choose two teaching areas in which to specialize, for which they are required to take a total of fourteen content courses; they may choose either two major areas (for which they must complete 7 discipline-specific courses each) or a major (7-9 discipline-specific courses) and a minor (5-6 discipline-specific courses) teaching area. The program includes 32 courses. Ten of these are core courses, which cover such topics as developmental learning theory, philosophy of education, pedagogical and curricular foundations, indigenous perspectives and diversity, classroom management, information communication technology (ICT) and pedagogy and a
professional placement portfolio. Six shared courses include foci such as adolescent issues and challenges and transitions in secondary education. One secondary specialization course is selected from topics like middle and senior phase curriculum and pedagogy, planning, literacies, and beginning professional practice. A total of fourteen discipline studies must be taken, which focus on the content area the candidate will teach. There is one elective course for which students may choose from a range of topics.

One hundred days of professional experience (i.e., ‘prac’, short for ‘practical’ experience) are included throughout the program. The College of Teachers mandates a minimum of 80 supervised days of a total minimum of 100 days of prac. Prac is tied to courses throughout the program such that six of the eight total semesters includes a prac assignment (see Table 1).

Table 1
Prac Schedule for Undergraduate Program

<table>
<thead>
<tr>
<th>Year</th>
<th>Semester</th>
<th>Days of Prac</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>10 days</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>15 days</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>15 days</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>15 days</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>25 days</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>20 days unsupervised</td>
</tr>
</tbody>
</table>

**Grad Dip program.**

The Grad Dip is a 1-year, full-time (or part-time equivalent) curriculum that results in a Graduate Diploma of Learning and Teaching. The program is designed for individuals who have previously earned a Bachelor degree in a field other than education
and wish to earn licensure to teach within that field. It may be completed on-campus or online. The program includes eight courses, four core and four secondary specialization courses. Core courses address topics such as classroom management, professional placement and portfolio, designing for learning and diversity. Secondary specialization courses address middle and senior phase pedagogy, literacies, and either competency based training and assessment or adolescent issues and challenges. The program includes 75 days of prac, which must be completed in at least two different schools.

<table>
<thead>
<tr>
<th>Year</th>
<th>Semester</th>
<th>Days of Prac</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1, 2</td>
<td>15 days</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>15 days</td>
</tr>
<tr>
<td>1</td>
<td>1, 2</td>
<td>25 days</td>
</tr>
<tr>
<td>1</td>
<td>1, 2</td>
<td>20 days</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>25 days (optional course)</td>
</tr>
</tbody>
</table>

Course structure.

While the course format of both the Grad Dip and undergraduate teacher education programs is typical of Australian universities, it differs from a U.S. context. It is worthwhile to note that there are two types of class experiences for every course enrollment; there are three if a prac is assigned to a course. When candidates enroll for a course, they select a tutorial time that works with their schedule and plan to attend the lecture that accompanies the course. Each course has one lecture, offered once a week to everyone enrolled in the course. Each course also has a tutorial (i.e., tut). Often a course
will have several sections of tuts, the number of which depending on enrollment for the course. While one individual (many times the full-time faculty member) will run the lecture, various individuals (sometimes full-time, often part-time academic staff) will facilitate the tut. The lecture is designed to be delivery of content. Typically grades are not assigned for attending (or if there is any opportunity, for participating in) lectures. Tutorials are intended to provide opportunities for learning activities and for the explanation of assessments. While lecturers are responsible for coordinating courses and delivering lectures, it is the tutors (i.e., the faculty responsible for facilitating tutorials) who are responsible for marking assessments.

Prac, while ‘attached’ to some courses, is somewhat separate in that meeting times for the course are not scheduled during the time candidates are on prac. For example, if candidates have twenty-five days (i.e., five weeks) of prac at the end of the semester, they will (hypothetically) attend the lecture and tutorial for the course to which the prac is attached for the first eight weeks; that class will then cease to meet for the following five weeks while out on prac and will sit for the exam for the class in one of the final two exam weeks of the semester.

**Context and Sample**

As this is a case study, the population of interest includes preservice teacher candidates at a medium-sized university in Queensland. This study utilizes data collected from participants \(N = 12\) from both the undergraduate \((n = 6)\) and Grad Dip \((n = 6)\) programs. Two participants are male and ten are female. Among undergraduate participants, two were 17-19 years of age; three were 20-22, and one was 31-39. Among
participants in the Grad Dip program, one was 23-25 years of age; two were between the ages of 31 and 39, and three participants were between 40 and 49 years old. The intended outcome of both the Grad Dip and undergraduate secondary education programs is to prepare candidates for licensure to teach (in this case, science) in years 7 through 12. These programs are billed as similar paths to the same end, but while the undergraduate program includes content courses, the Grad Dip is designed to allow candidates to draw upon knowledge gained in content courses from their previous degree.

A prior expectation was that potential differences in TPACK development may be attributable to differences in participant characteristics and program structure between the Grad Dip and undergraduate groups. For purposes of validity, data from participants were grouped by undergraduate and Grad Dip programs and compared. This comparison yielded no cause to analyze these groups as independent samples, as findings were not significantly different across most variables of interest. Chi-square tests were performed to test the null hypothesis of no association between program and each variable of interest (i.e., those relating to beliefs, self-efficacy, TPACK components and context). For instances in which greater than 20% of the cells had an expected frequency of less then 5, Fisher’s exact test was substituted (Cochran, 1954). While most results failed to reject the null hypothesis, any instance in which a significant difference ($p < .05$) was found between these groups has been noted and discussed in the findings.

**Sampling plan.**

Merriam (2009) contends that in the instance of case studies, sampling must be done twice: once at the case level (i.e., selecting the context) and again within the case
(i.e., selecting participants within the case). Yin (2009) describes this embedded case study design as one that focuses on a single context, but includes subunits within that context. In this case, each of the twelve participants is a subunit and the bounded case is this population of secondary preservice science candidates within the context of their university program in Queensland, Australia (see Figure 1).

![Diagram](image)

*Figure 1.* This embedded case study design (adapted from Yin, 2009) includes twelve units of analysis within a single case, bounded in a specific context.

The rationale for selecting the case for study was presented at the beginning of this chapter. A list of secondary science education candidates provides the sampling frame. A highly general minimum sample size recommendation for case studies is 3 to 5 participants, (Creswell, 2002); due to the tightly defined population of interest, the sampling frame includes the population as it existed in the case. Faculty and administrators were contacted prior to the site visit in order to gather as much information about the sampling frame as possible. Patton (2002) addresses the ambiguities common
in qualitative research in regard to sample size. While Lincoln and Guba (1985) recommend sampling to the ‘point of redundancy’ at which point further sampling produces no new information (Lincoln & Guba, 1985), Patton (2002) notes that this still does not yield quantifiable guidelines for sample size. He advises that sample size may be informed by events as the study unfolds, noting that the most essential inclusion is a strong and well-justified rationale for procedural decisions for sampling. This flexibility is inherent in emergent design (Patton, 2002).

Onwuegbuzie and Leech (2007) note that in qualitative studies, the researcher must be concerned with the following generalizations:

(a) from the sample of words to the voice; (b) from the sample of observations to the truth space; (c) from the words of key informants to the voice of the other sample members; (d) from the words of sample members to those of one or more individuals not selected for the study; or (e) from the observations of sample members to the experience of one or more individuals not selected for the study. (p. 107).

This study includes interviews of approximately one hour each with all preservice teacher candidates in the science education program, during which follow-up questions and member checking were used to probe for further understanding, increase internal validity. The interview protocol was developed through several iterations, including piloting, and experienced researchers overseeing the study agreed it yielded adequate power to capture participant voice. Additionally, twelve interviews were determined to be sufficient to adequately address the research questions, as the group was relatively homogenous.
Observations and document analysis of participant lesson plans served to inform interviews.

Onwuegbuzie and Collins (2007) describe 24 sampling schemes, explaining mixed purposeful sampling as an approach that blends multiple sampling strategies. Combination, or mixed, approach to sampling affords opportunities for flexibility and triangulation (Creswell, 1998). This study employed several sampling strategies for various aspects of data collection.

An opportunistic sampling approach was utilized for observation of classes within the secondary teacher preparation program. Observations were limited to courses that were being offered during the two-month site visit; as many classes and relevant interactions (e.g., formal and informal learning experiences, demonstrations of student work/teaching) as possible were observed during this time. Opportunistic sampling occurred after the study commenced and provided the flexibility to select cases as events unfolded (Onwuegbuzie & Leech, 2007). This is another reflection of the emergent design flexibility as described in Patton (2002, p. 244).

Snowball or chain sampling relies on participants to recommend or recruit additional individuals for the study (Onwuegbuzie & Collins, 2007; Onwuegbuzie & Leech, 2007); this strategy was employed to establish opportunities for interviewing preservice teacher candidates beyond those identified prior to the site visit as faculty, administrators and candidates referred additional potential participants. This common approach to purposeful sampling allowed new participants who met the criteria to be identified via reference from initial participants (Merriam, 2009).
**Data Collection Procedures**

Emergent design flexibility maximizes responsiveness and allows the research to make pragmatic adaptations as the study unfolds (Patton, 2002). Plans for data collection were pre-designed, but were adapted in field as the study progressed. While Lincoln and Guba (1985) provide a compelling rationale for a lack of a priori design decisions, which, they assert, constrain and operate in opposition to the intent of true naturalistic inquiry, they do call for consideration of some necessary design elements. This case study falls in between this purely naturalistic and a staunch deductive approach on the continuum. Like most research, the proposed design is influenced in part by practical considerations and resource limitations, but is driven mainly by the nature of the research problem. Plans for data collection were developed to align with the research problem and were subject to adaptation as necessary as opportunities emerged and new data was used to inform the progression of the study. As the intent of this study is to understand the development of TPACK among preservice secondary science teachers, some fluidity of design was necessary to accommodate some fairly individualized aspects of the research focus.

Data collection occurred mainly over an eight-week period in the research setting via a site visit; however, preparations were made well in advance and data analysis occurred after this time period. A gatekeeper, or individual with access into the population of interest, can help facilitate entry into a research context (Merriam, 2002, p. 205). The host researcher point of contact served in such a role, facilitating introductions to faculty and administrators who subsequently offered insights into observation opportunities and potential participants identification. Faculty and administrators were
contacted prior to the site visit. This approach to entry into the field is what Patton (2002) terms the ‘known sponsor approach’ whereby the well-respected member of the community of study vouches for the credibility of the researcher. An explanation of the study was presented to these key points of contact that expressed their willingness to support the research. This ‘reciprocity model’ aided in gaining entry and participation, as both faculty and administrators see benefits in gaining insights to their program through the study’s findings (Patton, 2002).

While a survey instrument, typical of a quantitative approach, was utilized to gather data on attitudes and self-efficacy for TPACK from preservice secondary science teacher candidates, qualitative measures are essential to gain adequate insight into the complexities such as personal experiences which shape teaching philosophy, knowledge and thought processes regarding use of the technology for secondary science instruction. Data collected via this instrument helped inform interviews with individual participants. The proposed methods of data collection include the questionnaire, observations, document analysis and interviews. Abbitt (2011) notes that the extent to which perceived affects demonstrated ability to plan and implement technology for instruction remains unclear. Provisions for assessing both perceived (interviews and survey) and demonstrated (document analysis) TPACK were planned. These strategies were utilized to understand and describe the nature of participants’ TPACK. Interviews probing for experiences that shape the development of TPACK, and observations helped triangulate this data.
Survey instrument.

An adapted version of a questionnaire designed by Schmidt et al. (2009) was used to gather information on attitudes and self-efficacy for TPACK from the twelve preservice secondary science teacher candidates in this study (see Appendix B). Schmidt et al. (2009) developed a survey instrument to measure preservice teachers’ development of TPACK called the Survey of Preservice Teachers’ Knowledge of Teaching and Technology. This survey addresses all components of the TPACK framework and includes demographic and open-ended items that address respondents’ perception of the modeling of TPACK by faculty in their teacher preparation program. Schmidt et al. (2009) provide instructions on scoring the survey instrument. Items pertaining to self-efficacy for TPACK use the following Likert-type scale: strongly disagree (1), disagree (2), neither agree nor disagree (3), agree (4), strongly agree (5); the value assigned to each category is identified here in parenthesis, but is not visible on the survey. A Cronbach’s alpha reliability coefficient shows the internal consistency for each of the subscales and ranged from .80 to .92 (see Table 3).

Table 3
Reliability of the TPACK Questionnaire Scores (from Schmidt et al, 2009).

<table>
<thead>
<tr>
<th>TPACK Domain</th>
<th>Internal Consistency (alpha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Knowledge (TK)</td>
<td>.82</td>
</tr>
<tr>
<td>Science Content Knowledge (CK)</td>
<td>.82</td>
</tr>
<tr>
<td>Pedagogical Knowledge (PK)</td>
<td>.84</td>
</tr>
<tr>
<td>Pedagogical Content Knowledge (PCK)</td>
<td>.85</td>
</tr>
<tr>
<td>Technological Pedagogical Knowledge (TPK)</td>
<td>.86</td>
</tr>
<tr>
<td>Technological Content Knowledge (TCK)</td>
<td>.80</td>
</tr>
<tr>
<td>Technological Pedagogical Content Knowledge (TPACK)</td>
<td>.92</td>
</tr>
</tbody>
</table>
While this instrument was designed for early childhood majors and is not specific only to science, it has been tested and revised in multiple iterations and, with slight modifications, is a highly appropriate instrument for this study. In a review of the development of methods and instruments for assessing TPACK, Abbitt (2011) notes that the Survey of Preservice Teachers’ Knowledge of Teaching and Technology is a well-tested measure and may be a highly useful resource for the assessment of TPACK development within a teacher preparation program. Publication of this survey included express permission to utilize the survey instrument with the provision that the details of the study for which it is utilized are provided to the first author (see Appendix C).

**Interview protocol.**

Patton (2002) describes four types of interview structures along a continuum. This structural continuum includes highly informal conversational interviews; interview guides, which include a list of topics to address; more structured, standardized open-ended interviews in which questions are scripted; and the highly structured closed, fixed-response interview format, which is similar to reading a multiple choice questionnaire aloud to the subject (Patton, 2002). Interviews in this study fell somewhere between interview guides and standardized open-ended format.

Following a review of the literature and formation of the research questions, an initial interview protocol was designed and discussed with a panel of experts in higher education. The protocol was pared down to eliminate items that yielded extraneous data to include only the scope of the research questions. Some additional items were added to capture necessary data. The protocol was then piloted with four preservice teacher
candidate volunteers from Ohio University. Following the pilot interviews, the protocol was revised again to include probes to draw out data that was not initially considered in the design of the protocol and to reword items for clarification of intent. Upon arrival to the research site, the protocol was revised further for clarification after conferring with several faculty members in the School of Education regarding context-specific terminology. The final interview protocol is included in Appendix D.

Key topics were outlined and critical questions were included in the protocol to be used with all participants, in order to thoroughly broach each area of TPACK development while allowing flexibility for related probing and follow-up questions. This approach yielded consistent coverage of principal topics, which were systematically compared and analyzed across respondents while affording a conversational tone and freedom for the researcher to use discretion in pursuing unscripted or unanticipated yet germane issues that arose. As Siedman (2006) explains, the intent of interviewing is not simply to get answers to a list of questions or support hypotheses; rather, the intent is “understanding the lived experience of other people and the meaning they make of that experience” (Siedman, 2006, p. 9). According to Siedman (2006), such an understanding cannot be gained from strictly scripted questions.

Patton categorizes six types of questions, including behaviors/experiences, opinions/values, feelings/emotions, knowledge, sensory, and background into past, present, and future tenses (Patton, 2002). Five of these categories (excluding sensory) were addressed in the interviews within varying tenses (i.e., past, present and future). For instance, in an interview with a preservice teacher candidate, a behavior/experience
question may probe the candidate’s prior (past) experience as a K-12 student in the science classroom and whether they saw technology integration modeled; opinions/values regarding the use of technology and the role it might play in their own science classroom (future) will be probed; feeling/emotion questions will review issues concerning the way the participant reacts to new technology, including levels of interest and self-efficacy (present); knowledge questions may address specific aspects of TPACK, including issues such as Web 2.0 tools (technology), constructivist learning strategies (pedagogy), or the nature of science (content knowledge); demographic questions will garner information such as in which program (i.e., graduate diploma or undergraduate) the participant is enrolled, which could potentially be useful in identifying trends between program and beliefs, self-efficacy or reported TPACK-related experiences. Candidate interviews yield greater depth of understanding of candidate experiences, the meaning participants attribute to these experiences, and the impact they have on their TPACK development.

**Observations.**

Observations were used to gather data on TPACK-related experiences in the university context. Field notes were initially intended to be coded for evidence of TPACK and to determine which components were present, to what extent and how frequently. They were generated from observations of multiple class sessions in the undergraduate and Grad Dip programs, student portfolio presentations and professional seminars (e.g., an information session from Education Queensland). It was determined at the time of analysis that the coding of field notes to identify the presence of TPACK was not in line with the nature of the research questions (see Data Analysis Procedures). The
greatest value of observations in this study was the familiarity of context, including shared experiences between researcher and participant that were often referenced during interviews, and opportunities for chain sampling generated from additional contact made with faculty and students within the program.

**Document collection.**

Documents were intended for analysis from the same perspective of observations (i.e., to determine where, how and to what extent TPACK was present in the program context). While ultimately documents were not coded to identify TPACK presence (see Data Analysis Procedures), they provided contextual information as well as talking points for the interviews. Program descriptions, course syllabi, assignment guides, supplemental course documents, and literature from Education Queensland (i.e., the Department of Education in Queensland, Australia) all provided valuable familiarity of context that was critical to communication during interviews and during data analysis. Lesson plans were collected from participants to discuss during the interviews as examples of enacted TPACK-related beliefs and knowledge. Participants were asked to explain their lesson plans, discuss sequencing, prioritization and rationales for their instructional decisions and indicate from where their sources of knowledge and ideas stemmed (e.g., a participant might cite that they have been taught in their education courses that assessing prior knowledge is important or that they planned to do an activity that their high school science teacher did with their class when they were a student).
Data Analysis Procedures

Yin (2009) identifies four principles of quality analysis applied in this study. The analysis attends to all evidence; no data was left unaddressed due to lack of conformation to the findings and no ‘loose ends’ were left. Where possible, all foreseeable rival explanations have been addressed, either shown to be unsupported by the evidence or listed as potential paths for future research. Analysis and discussion of findings address the main research question, and prior expert knowledge will be applied in the analysis of the case study (Yin, 2009).

The study includes both quantitative and qualitative data analysis, though quantitative analysis is limited to descriptive statistics to aid in providing an overview of the case and to examine variation within the sample. All data was de-identified prior to analysis and pseudonyms were employed. Chi-square and Fisher’s exact tests were employed to test for any difference between Grad Dip and undergraduate data sets for variables of interest related to each research question. The Statistical Package for the Social Sciences (SPSS) version 22 was employed for all quantitative data entry, manipulation, and analysis.

Field notes and document analysis.

The ambiguity and lack of precise and prescriptive methods for case study data has been noted in the literature (Miles, 1979; Patton, 2002; Yin, 2009). In practice, rules and procedures for data analysis are often not formulated until after the data has been collected (Lincoln & Guba, 1985). Both observational field notes and collected documents were generated/gathered for analysis. The intent was to ascertain the presence
of TPACK within the program (i.e., in which contexts and how pervasive and integrated it is). However, as the intent of this study is to understand which experiences meaningfully impact preservice secondary science teacher candidates, it was determined that the inclusion of field notes and document analysis from this more evaluative perspective was not in line with the nature of the question (i.e., which of these experiences are having an actual impact?). The reality that this study is concerned with is not which TPACK components are being planned for or addressed within the program, but rather which experiences or sources of knowledge are truly shaping technological pedagogical content knowledge in preservice secondary science teachers.

Observations and document analysis, while extremely useful for understanding the context and, particularly in the case of observations, making critically important connections, were not analyzed. This approach would place more value on an external evaluation of the program than the participant’s perspective and would not be inclusive of any experiences upon which participants draw that are external to the university program. The decision to exclude field notes and document analysis afforded more accurate alignment with the intent of the study as well as the ability to extend analysis of context beyond the university program, providing a far more comprehensive understanding of the sources which shape TPACK in the population of interest.

**Analysis of survey data.**

Data from the survey was utilized to address research question 2: What are the levels of self-efficacy of the preservice teacher candidates regarding TPACK and what experiences are shaping these? Individual scores were utilized for a chi-square test of a
null hypothesis that there is no difference between the Grad Dip and undergraduate group in regard to self-efficacy for TPACK. This was executed in order to determine whether analysis should proceed with all participants as one case or if data should be analyzed as two separate samples. An average score was calculated for each TPACK component for each participant. A case average was then calculated for each TPACK component. Items regarding the percentage of time TPACK is effectively modeled in the university context (by education instructors, other university instructors, or mentor teachers during prac) were analyzed in the same manner to supplement findings for research question 3: To what extent has TPACK been developed through experiences in the secondary science teacher preparation program?

**Analysis of interview data.**

The Computer-Assisted Qualitative Data Analysis Software (CAQDAS) QSR-NVivo version 10.1.0 was utilized for the organization and analysis of interview data. Yin (2009) offers some basis for initiating the process of ‘playing with’ the data, grouping information, organizing evidence into a categorical matrix, charting frequencies or events, calculating means and/or variances of these events to uncover potential relationships and organizing data chronologically. Creswell (1998) provides general guidance on data processing and reporting; this includes organization of data, reading, and memoing (which includes forming initial codes), description of the case and context, classification via pattern identification among categories, interpretation and presenting a narrative. Such strategies were utilized to elucidate relationships in the data.
A priori codes and code categories were arranged by research question, and enumerative approach to analysis was employed to understand the frequency of which experiences that shape TPACK were attributed to various contexts. Codes regarding beliefs (see Table 4) about learning, science, teacher-student relationship and technology address research question 1: What are the beliefs of pre-service science teachers regarding technology, pedagogy and content?

Table 4
Coding Structure of Beliefs, Sources (participants) and References

<table>
<thead>
<tr>
<th>Code (Beliefs)</th>
<th>Sources</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>building on prior knowledge</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>experiential</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>applied</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>contextual</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>inquiry</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>unable to define</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>understanding something new</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>empirical</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>how things work</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>unable to define</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>everything</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>what it isn’t</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Teacher-Student Relationship</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relationship</td>
<td></td>
<td></td>
</tr>
<tr>
<td>student-driven</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>teacher-centered</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>team</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Student Role</td>
<td></td>
<td></td>
</tr>
<tr>
<td>director</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>follower</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>unsure</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>willing participant</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Code (Beliefs)</td>
<td>Sources</td>
<td>References</td>
</tr>
<tr>
<td>---------------</td>
<td>---------</td>
<td>------------</td>
</tr>
<tr>
<td>Teacher Role</td>
<td></td>
<td></td>
</tr>
<tr>
<td>director</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>facilitator-guide</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>mentor</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>motivator</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>Technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Affordances</td>
<td></td>
<td></td>
</tr>
<tr>
<td>classroom extension</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>classroom management</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>display or projection</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>efficiency</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>organization</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>memorization</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>repository</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>motivation &amp; interest</td>
<td>9</td>
<td>22</td>
</tr>
<tr>
<td>multi-modal</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Considerations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>add-on</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>cost-benefit</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>instructional alignment</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>relevant skill development</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Constraints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>student ability</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>teacher ability</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>access</td>
<td>9</td>
<td>22</td>
</tr>
<tr>
<td>barrier to skill development</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>distraction</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>time consuming</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Level of Interest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>enthusiasm</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>intimidation</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>value recognition despite aversion</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>stick with what you know</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Orientation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Didactic</td>
<td>12</td>
<td>115</td>
</tr>
<tr>
<td>Student-centered</td>
<td>11</td>
<td>32</td>
</tr>
</tbody>
</table>
Orientation was also coded, as any reference to student-centered or didactic approaches to teaching and learning was noted to provide greater insight into the orientation of experiences cited by participants. Because these codes were applied to any experience referenced (and not just those in which participants were expressing their beliefs about teaching and learning), these codes have been aligned with research question 4 regarding the sources of TPACK preservice secondary science teachers draw upon, as it provides insight into the nature of such experiences. It should be noted that, while positive and negative experiences are coded from the participant’s perspective (i.e., their value judgment), the orientation is coded from the researcher’s perspective. This is important because at times, participants discussed the use of motivational strategies as student-centered pedagogies when, really, they were describing instances of direct instruction. This issue is addressed in the findings.

Codes regarding self-efficacy (see Table 5) were used to supplement findings from analysis of survey data in addressing research question 2: What are the levels of self-efficacy of the preservice teacher candidates regarding TPACK?

<table>
<thead>
<tr>
<th>Code (Self-Efficacy)</th>
<th>Sources</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td>11</td>
<td>55</td>
</tr>
<tr>
<td>moderate</td>
<td>12</td>
<td>42</td>
</tr>
<tr>
<td>low</td>
<td>12</td>
<td>66</td>
</tr>
</tbody>
</table>
Codes regarding context (see Table 6) were cross-referenced with codes for TPACK (see Table 7) as well as self-efficacy. Cross-referencing with self-efficacy allowed for the extension of findings beyond basic measurement of TPACK-related self-efficacy (as ascertained via the survey instrument) to understanding from which contexts experiences were contributing to high, moderate, and low levels of self-efficacy. This is pertinent to the second half of research question 2: What are the levels of self-efficacy of the preservice teacher candidates regarding TPACK and what experiences are shaping these?

Table 6
Coding Structure of Contexts, Sources (participants) and References

<table>
<thead>
<tr>
<th>Code (Structure of Contexts)</th>
<th>Sources</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informal Edu</td>
<td>12</td>
<td>61</td>
</tr>
<tr>
<td>Intuition-Personal Preference</td>
<td>12</td>
<td>48</td>
</tr>
<tr>
<td>Non-Teaching Work Experience</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>Professional Development</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>When I Was In School…</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Primary</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Secondary</td>
<td>12</td>
<td>66</td>
</tr>
<tr>
<td>Tertiary (previous study)</td>
<td>8</td>
<td>29</td>
</tr>
<tr>
<td>Teaching Experience</td>
<td>2</td>
<td>23</td>
</tr>
<tr>
<td>Uni</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edu Courses</td>
<td>12</td>
<td>69</td>
</tr>
<tr>
<td>ICT course</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Other USW Courses</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Prac Experience</td>
<td>8</td>
<td>67</td>
</tr>
<tr>
<td>Program</td>
<td>11</td>
<td>31</td>
</tr>
<tr>
<td>Science Courses</td>
<td>7</td>
<td>17</td>
</tr>
</tbody>
</table>

Cross-referencing university-specific contexts with TPACK addresses research question 3: To what extent has the development of TPACK been addressed in the science teacher
preparation program? University contexts were then consolidated into a “Uni” category and added to findings from which contexts external to the university experience were cross-referenced with TPACK. This addresses research question 4: What sources of TPACK do preservice science teachers draw upon in planning for instruction?

Table 7  
*Coding Structure of TPACK, Sources (participants) and References*

<table>
<thead>
<tr>
<th>Code</th>
<th>Sources</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK (lacking)</td>
<td>8</td>
<td>24</td>
</tr>
<tr>
<td>CK +</td>
<td>11</td>
<td>41</td>
</tr>
<tr>
<td>CK -</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>PCK (lacking)</td>
<td>10</td>
<td>27</td>
</tr>
<tr>
<td>PCK +</td>
<td>12</td>
<td>41</td>
</tr>
<tr>
<td>PCK -</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>PK (lacking)</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>PK +</td>
<td>12</td>
<td>53</td>
</tr>
<tr>
<td>PK -</td>
<td>12</td>
<td>37</td>
</tr>
<tr>
<td>TCK (lacking)</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>TCK +</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>TCK -</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TK (lacking)</td>
<td>11</td>
<td>49</td>
</tr>
<tr>
<td>TK +</td>
<td>11</td>
<td>47</td>
</tr>
<tr>
<td>TK -</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>TPACK (lacking)</td>
<td>12</td>
<td>61</td>
</tr>
<tr>
<td>TPACK +</td>
<td>12</td>
<td>33</td>
</tr>
<tr>
<td>TPACK -</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>TPK (lacking)</td>
<td>11</td>
<td>50</td>
</tr>
<tr>
<td>TPK +</td>
<td>9</td>
<td>26</td>
</tr>
<tr>
<td>TPK -</td>
<td>6</td>
<td>9</td>
</tr>
</tbody>
</table>

Note that positive and negative references to TPACK are as evaluated by the participant (not the researcher) and that both positive and negative experiences influence/shape/form participant's TPACK (or components thereof). Components labeled
as lacking indicate participant-identified opportunities for TPACK to have been shaped/formed. These are experiences that participants explicitly cited which inform their TPACK. Positive experiences are those which they found useful, effective, successful; negative are those which they felt were ineffective or detrimental to their learning; and lacking components are references to things they noted were not present.

Given the multiple variables of interest, it proved useful to develop several matrices for the aforementioned cross-referencing of codes, as described by Patton (2002). These were employed to identify from which contexts participants cite experiences that influence various aspects of their TPACK development. Patton (2002) notes that this process of identifying impact factors can involve induction, deduction and/or abduction. Deductively, prior research on TPACK and literature on preservice teacher development informed not only the research questions, but the coding structure as well. A priori codes established for TPACK components (i.e., TK, PK, CK, PCK, TPK, TCK and TPACK) were used to identify TPACK development through the expression, recollection or demonstration of beliefs, ability or knowledge. Codes for orientation (i.e., student-centered and didactic) were formed prior to analysis. Coding categories for context and beliefs were pre-established based on the research questions; however, codes about beliefs on teaching, science, and technology as well as those for context emerged inductively within these categories.

Matrix coding queries, executed in NVivo, were utilized to address research questions and to inform the design of visual diagrams. Such queries were used to organize data by Program (i.e., Grad Dip vs. undergrad) against TPACK/Context, Beliefs
(i.e., about Learning, Science, Teacher-Student Relationship, Technology) and Orientation (i.e., Didactic, Student-Centered) for comparison by group in SPSS.

**Visualization of interview data.**

Besides the use of tables and standard bar and pie charts, results of matrix coding queries from cross-referencing TPACK experiences with context were employed in the design of unique diagrams to communicate findings. These diagrams a) map references of TPACK components to program contexts (i.e., education courses, science courses, electives, and prac); b) illustrate the incidence and extent of integration of TPACK components across program contexts; and c) visually elucidate a broader, more complete conceptualization of the contexts and experiences from which preservice teachers are drawing upon in planning their own instruction (i.e., extend the frame of reference beyond the program to include references to such contexts as informal learning, work-related, prep-high school experiences, etc.). To create these diagrams, each data point (i.e., reference to a TPACK-related experience) was given a value of .1 inches. Numerical totals for each positively or negatively referenced component of TPACK were multiplied by .1 to determine the size of a circle representing the component. Some diagrams were scaled to fit the page of this document and diagrams should not be compared against one another, though all circles within a diagram are proportionately scaled for an accurate visual comparison. These circles are arranged and bound visually within their referenced context. The presence (or absence) and size of the circles within a context provide a visual indication of how frequently preservice secondary science teachers in the study referenced both positive and negative TPACK-related experiences and in what contexts...
these influential experiences occur. These diagrams are included with relevant findings throughout chapter four.

Credibility

A variety of credibility techniques were utilized in an endeavor to avoid bias, ensure rigor in data analysis and verify credibility of conclusions. Yin (2009) notes that a major benefit to the case study approach is the ability to utilize various sources of data collection in ‘converging lines of inquiry,’ which includes continuous substantiation of evidence between various data collection methods, all which triangulate on the same set of research questions (pp. 115-116). The sampling strategy employed in the current study has inherent benefits in regard to credibility. Miles and Huberman (1994) contend that a mixed purposeful sampling strategy, employed in the current study, assists in data triangulation. Triangulation refers to the use of multiple data points, investigators, methods and/or theories (Lincoln & Guba, 1985; Nastasi, & Schensul, 2005; Patton, 2002). Stake (1995) explains that data triangulation is particularly important for credibility in case study research. Multiple methods are utilized in the current study, including the interviews, a survey instrument and some level of document analysis in discussing participants’ sample lesson plans; this is one strategy to improve qualitative research validity (Johnson & Christensen, 2012). The utilization of both quantitative and qualitative data collection and analysis strategies can enrich understanding through triangulation and corroboration of results (Nastasi, & Schensul, 2005).

Brantlinger, Jimenez, Klingner, Pugach, & Richardson (2005) provide a list of credibility measures for qualitative research, many of which are applicable to this study.
Peer debriefing was utilized, in which data and preliminary conclusions were shared with experts in the field in order to gain critical feedback. Colleagues served as external auditors, reviewing inferences to verify that they are based solely on findings from the data. Thick description is employed by including sufficient quotes and specific evidence to support reported findings in the subsequent chapter with the intent to yield particularizability, or sufficient detail to allow the reader to assess transferability (Brantlinger et al., 2005). An audit trail was created to provide well-organized documentation of the research; this was useful for a detailed review of procedures and data and could help facilitate replication studies (Nastasi & Schensul, 2005).

**Researcher reflexivity.**

Researcher reflexivity, or the acknowledgement of the researcher’s own perspective and/or biases (Brantlinger et al., 2005), is an important facet of qualitative research as it identifies potential bias and a priori expectations. My experiences, values, and interests have influenced the selection of my research topic and the design of this study. My experience as an educator began in 2003 after graduating with a Bachelor of Music in Music Education. I began my teaching career as the sole band director for a rural, but well-funded school district in Ohio that was ahead of the state curve in technology adoption. In addition to teaching grades 6-12 band, I planned and taught two middle school computer technology classes. I had no formal preparation for teaching computer technology, but I had a penchant for designing and mashing up media, a propensity to play with new technologies and some gaps in my teaching schedule. As the class was mine to design, I focused mainly on creating multimedia. I touched on
fundamental constructs related to hardware and software and (very basically) how the World Wide Web works, a bit on copyright (though I took many liberties in the name of ‘fair use’ at the time), but my main focus was on tying students’ interests to technology. I designed activities to build skills I felt were important (many of which I came to know as ‘new media literacies’ (Jenkins, Purushotma, Clinton, Weigel, & Robinson, 2006) during my later graduate study) and allowed students to determine the focus of their projects. For example, students would create and present multimedia presentations, design websites and shoot and edit videos, all with specific criteria developed in alignment with the learning objectives, but could focus the project on the topic of their choice. I found this to be an effective way for students to infuse their own personality and interests into their work; they took ownership of their work and were highly motivated to work on projects where they had a great amount of freedom and choice. Some students created presentations to teach me about various farming equipment and processes, as they were far more knowledgeable on these topics than I, and I was encouraged by their enthusiasm and pride in their ability to educate me as their teacher. Other students focused on their favorite musicians, athletes or other pop culture icons, but they were working diligently and building skills, so I considered it a teaching and learning success. Other teachers learned from the students about what they were doing in computer class and asked me to support their own technology integration efforts in their classrooms; the following year, I was appointed to the position of district technology integration specialist to afford me more time to support fellow teachers. After three years, I relocated to Florida and taught elementary computers at a charter school. The only qualifying criteria to gain
certification in this content area was a passing score on a content test, which I achieved with no formal technology training. The focus of my third through fifth grade classes, as relayed to me by administration, was intended to be on typing and using software designed specifically to ‘practice’ for state tests. I admittedly did not value these activities, and a lack of awareness from administrators allowed me to continue teaching skills I felt would better benefit my students in the long run. In this setting, I typically tied projects to topics students were learning about in their other subjects (e.g., students learned to search for and evaluate information, locate relevant media, save it, reformat or edit it, and develop an interactive presentation about the solar system, as they were covering that in science). I still found the creative use of technology and freedom of design was enough to motivate most. I found it easy to develop report with students, and found praise for creativity (in design and technical problem-solving) went a long way in generating students’ desire to go above and beyond the minimum requirements for assignments. Several students would even assign themselves their own technology ‘homework’ and bring in projects they’d developed on their own time to proudly share with me.

After two years of teaching in Florida, I returned to my home state of Ohio. I’d been teaching technology for five years without any formal training in the content area, and I was not certified to teach solely technology in this state, so I commenced a Master’s program in Computer Education and Technology. I began my Ph.D. in Instructional Technology near its conclusion. I felt I’d had a fair amount of success in my teaching career up to that point, though my personal standards for gaging this were focused largely
on the ability to motivate and engage students, though I did see direct connections with achievement. Teaching seemed to be something I was innately good at, and, while I was excited to broaden my familiarity with various technologies and build my technical skill though a Master’s program, when it came to teaching, I tended to think of it more as a talent. I learned a great deal about content in my undergraduate degree, and I was interested in learning a new content area in my Master’s; both degrees included relevant theories, pedagogies and philosophies, but they all seemed to align with what I was doing intuitively. I considered them useful for validation but not as requisite knowledge for good teaching, as I’d seemed to have great ‘success’ without explicitly drawing upon this knowledge previously.

Throughout my graduate study, I became familiar with the TPACK framework and instructional design principles. In my initial ignorance, TPACK seemed an unimpressively intuitive framework to categorize considerations in teaching, and the instructional design process seemed little more than an unnecessarily tedious approach to lesson planning. With further study, experience and greater understanding, both have greatly influenced my conception of teacher knowledge and manner in which I plan for instruction. I designed and taught many classes as a graduate assistant and, eventually, as a faculty member in the Instructional Technology program. My emphasis on project-based, constructivist learning activities persisted, as did my value of customization. I continued to design projects that afforded a great deal of flexibility for learners in order to promote authenticity and relevance. Learners in my classes were expected to tailor all projects to their professional context, whether they were school teachers of various grade
levels and content areas, graduate students aiming for positions in higher education or aspiring instructional designers working in various industries. I often designed an entirely new learning environment for my courses, sometimes using a wiki or personally hosting a site that I custom designed from a blogging platform. I put a great deal of energy, thought and time into the user experience of my classes, as they were mostly online. My decisions, however, seemed to be based less and less on intuition and more out of consideration of what I’d learned throughout my graduate experience. Because I was teaching future and inservice teachers about teaching or instructional designers about the process of instructional design, I tried to make instructional decisions explicit (i.e., from a student-centered approach, I would often ask students to discuss the various facets of the instruction planned for them in my classes – how it connect to theory and pedagogy; and from a teacher-centered approach, I would often provide a rationale for the learning activities and assessments in an attempt to tie theory to practice.

I applied for the East Asia Pacific Summer Institute (EAPSI) program through the U.S. National Science Foundation (NSF) in partnership with the Australian Academy of Science in order to fund my research in a context somewhat similar to my own, but in which major initiatives were being implemented to focus on the development of TPACK in preservice teachers, as my desire was to glean useful insights with potential to inform teacher preparation efforts in this area. I spent three months living on campus at my research site in Queensland while collecting data. After returning to the U.S. for a year of data analysis, I have since relocated to Sydney, New South Wales as a permanent resident and am currently working as a blended learning advisor, designer and e-learning
specialist in the School of Education at a large university. I maintain a focus on content and pedagogy and include an explicit ‘rationale’ section that aligns these to the activity when designing learning activities and encourage the faculty I support to do the same. I believe this attempt to make implicit expert knowledge explicit for learners helped make these connections more apparent for myself as well.

Reflecting on my time as a beginning teacher, I notice a focus on student motivation and creativity. While anecdotally (in working with preservice and novice teachers) as well as through this study, I have noted student motivation seems a concern of many beginning teachers (and a measuring stick by which they determine a teacher’s effectiveness); creativity and the ability to customize and create is something I value personally. Like many of the preservice and novice teachers I have encountered, my early attempts to increase motivation (i.e., allowing students to select the topic of their technology projects) were arguably somewhat superficial and driven by my own value of creative freedom. As I gained experience in teaching, my focus turned to pairing technology with content-specific topics, though early attempts were driven less by the pedagogy and content of the subject to which I was pairing (e.g., science, social studies) and more informed by the technology and skills included in my objectives as the technology teacher. In my experience as a university instructor, because most individuals enrolled in my classes were preservice or practicing teachers, my focus was always on relating the learning back to the learner’s authentic context. In asking learners in these classes to plan technology facilitating learning experiences for their students or clients, I always stressed a focus first on content and pedagogy, with the alignment of technology
last to ensure that the tool wasn’t driving the design. I also made a concerted effort to be transparent in my teaching. I see my previous outlook on teaching as a talent as somewhat symptomatic of the theory/practice gap and somewhat due to the (what I have perceived to be) natural tendency to measure one’s success as a beginning teacher by the ability to motivate students and interest them in the topic at hand.

Reflecting on the evolution of my values and knowledge as a technology teacher and teacher educator led me to an interest in the development of TPACK in teacher preparation programs. I was curious as to what experiences most impacted beginning teachers. I wondered how much preservice teachers were drawing from their teacher preparation program versus their experience as a student or even from other life experiences – what experiences are impacting the development of their TPACK and how do they ‘know’ what they know?

As a teacher educator, I hold certain related values and perspectives. I am an advocate of student-centered learning, particularly of project-based learning, and I believe authenticity and transparency in teaching are important in teacher preparation, as we are (for better or worse) always modeling practice when our learners are preservice teachers. Every effort has been made to obtain, analyze and present the data and findings without applying these values. While I may hold opinions about the findings based on my personal perspectives, my goal in this study was to carry out data collection and analysis as neutrally as possible, as my real interest is not in determining the ‘value’ or ‘correctness’ of preservice teacher knowledge, but to determine its origins. That is, the aim of the study is not to measure or evaluate TPACK, but rather to identify factors in the
development of the phenomenon among preservice secondary science educators. When beliefs and values influence perceptions of success in teaching, which experiences do beginning teachers draw upon to model in their own plans for practice? In the search for causality (e.g., determining which factors/contexts may impact TPACK development and in what ways), the researcher-as-detective approach was taken, as alternative explanations (i.e., contexts, experiences, sources of knowledge) were probed in interviews; a skeptical approach to considering causality aided in combating bias and preconceived notions (Johnson & Christensen, 2012).

**Chapter Summary**

This chapter presented a rationale for the selection of the current case. A detailed description of the context was provided, including program structure and explanations of the undergraduate and Grad Dip programs and course structure. Both the population and sample were described along with a sampling plan. Data collection procedures, including details about the survey instrument and interview protocol as well as document collection procedures, were explained. Initial plans and updates to procedures for data analysis were detailed for each of the data types, along with a rationale for these changes. The development process for the visual representations of interview data (presented in the findings) has been explained. Credibility measures, including researcher reflexivity, have been addressed.
Chapter 4: Findings

The purpose of this study was to ascertain, through an embedded case study, what experiences shape the development of TPACK in secondary science education majors at the research site, a medium-sized university in Queensland, Australia.

The overarching research question, which guided this study, was: What are the key factors that influence the development of TPACK among preservice science teachers at this Queensland university?

Relevant subquestions, also specific to the context, were formed to help specifically target multiple facets of this research question in order to thoroughly address such a complex phenomenon. These subquestions were:

1. What are the beliefs of preservice science teachers regarding technology, pedagogy and content?
2. What are the levels of self-efficacy of the preservice teacher candidates regarding TPACK and what experiences are shaping these?
3. To what extent has TPACK been developed through experiences in the secondary science teacher preparation program?
4. What sources of TPACK do preservice science teachers draw upon in planning for instruction?

Questions 1 and 2 are aimed at better understanding related issues and providing rich description, while questions 3 and 4 target the essence of the main research question, with question 3 targeting the program (i.e., university-specific context) level, and question 4
extending beyond the university context to encompass all experiences to which TPACK development is attributed.

The findings discussed within this chapter are based on the analysis of interview and survey data, as observations and document analysis were used only to inform interviews, as noted in chapter 3 (see Data Analysis Procedures). Transcripts of 12 participant interviews served as the primary form of data and were coded for beliefs about teaching and learning, science and technology, context, self-efficacy and TPACK using QSR-NVivo software. A priori codes derived from the research questions included those for TPACK and its components as well as high, moderate and low self-efficacy codes used to supplement survey data. Pre-determined code categories were formed in alignment with research questions for context and beliefs, though the actual codes within these categories were formed inductively from the data. Interviews were structured so as to draw out sources of beliefs and knowledge in alignment with the intent of the study. An enumerative approach to analysis was employed to understand the frequency of which experiences that shape TPACK were attributed to various contexts. Survey data was used to assess TPACK-related self-efficacy among participants and to supplement data regarding the frequency of modeled TPACK within the teacher education program in the university context.

Diagnostics

SPSS was utilized for statistical analyses of data to determine whether a significant difference exists between the Grad Dip and undergraduate participants for each variable of interest. Chi-square and Fischer’s exact tests were performed to test the
null hypothesis of no association between program (i.e., Grad Dip or undergraduate) and each variable of interest. Results did not indicate a significant difference between groups in most cases; however, two instances were identified in which it may be more suitable to examine the data as two separate groups.

The chi-square test identified an association between program and all recorded context-specific references (i.e., interview codes) to CK, \( \chi^2 (1, N=63) = 7.34, p = .007 \). While Fisher’s exact test yielded an association between program and university-specific references to CK (\( p = .003, \) FET), there was no relationship found between program and references to CK outside of the university context (\( p = .70, \) FET). Additionally, a chi-square test identified an association between program and all context-specific references to TK \( \chi^2 (1, N=96) = 5.11, p = .02 \). Further analysis yielded an association between all university-specific references to TK \( \chi^2 (1, N=44) = 4.62, p = .03 \); however, there was no relationship found between program and references to TK outside of the university context, \( \chi^2 (1, N=52) = .74, p = .39 \). No relationship between program and references to TK outside of the university context (\( p = .13, \) FET) when these specific analyses were targeted.

Therefore, findings based on references to CK and TK distinguish between Grad Dip and undergraduate groups within the university context only (i.e., research question 3). For all other scenarios, participants were analyzed as one group.
Research Question 1

What are the beliefs of preservice science teachers regarding technology, pedagogy and content?

Findings related to this question are the results of the analysis of interview data, coded for beliefs regarding technology, learning and the student-teacher relationship (pedagogy) and science (content).

Beliefs regarding technology.

References to technology were coded inductively for belief and value statements. Half of all references were to some affordance (i.e., benefit) of technology, while 35% of references were to constraints and 15% included some neutral consideration for the use of technology.

Affordances.

In terms of affordances, the most commonly cited was motivation and interest, accounting for 30% of references, while organization accounted for 26% (see Figure 2). Abby, a graduating student from the undergraduate program, explained how the use of technology to motivate students is ‘better teaching’:

Abby: I really underestimate the power that the use of technology has in engaging students, and that’s one of the things that the university sort of brought to life. They use statistics and case studies to show us the different impacts that some of the things we can do as teachers will have on our students.

Researcher: Was it mostly reading research about what technology can bring to teaching?
Abby: Definitely – listening to kids talk about it– like have the videos they show sometimes in class. I know they like to use computers to type instead of writing because they don’t like to write. I consider that laziness, but…One video showed us how much more engaged the students were just by using a SMART Board. Like – that killed me! I could be writing this on a normal board and you could be twittling your thumbs, but because I’m using a SMART Board you’re like ‘yes – let’s put this on there as well!’ I just don’t understand it. I know that it makes it better teaching, but I don’t understand why. It’s something new and exciting – that I get, but…

Researcher: So you see it as more of a novelty effect?

Abby: Absolutely.

(interview, August 8, 2013)

Organization, as an affordance of technology, represented two cited applications: use as a repository (e.g., references to the usefulness of websites for storing course content or the consolidation of content accessible via a single electronic device rather than multiple textbooks) and organization for memorization (e.g., concept mapping, specifically cited by Arnold (interview, August 13, 2013) as a memorization tool to “help remember things so they can pass the exams”, applications for drilling terminology and study guides).

Display or projection and classroom extension were the third most cited affordances of technology, which referenced the ability for teachers to project content onto screens for student viewing.
Classroom extension, cited on ten occasions, included the notion of extending access to information beyond the classroom (e.g., the ability for students to search the Internet or the ability for the instructor to show videos of science phenomena that are either too large or small in scale to see or are otherwise inaccessible due to cost, safety, distance, etc.).

Efficiency was referenced six times and the multi-modal properties of technology were referenced three times.

Classroom management was also referenced by three different students, and all citing the affordance of PowerPoint in allowing teachers to lecture without turning their back to the class.

*Figure 2.* Perceived affordances of technology.
**Constraints.**

The majority of constraints cited by participants are external to the technology itself (see Figure 3). Access issues account for 46% of the constraints and issues regarding ability account for 27%, with concerns over teacher ability to use technology (cited in 8 instances) outweighing those of student ability (cited in 5 instances). Only 27% of all referenced constraints involve the technology itself. The main concern is the amount of time it takes to utilize technology for teaching and learning. Some time constraint concerns deal with the time it takes teachers to learn the technology, as Janice noted of her prac experience: “Some of them had SMART Boards, but I didn’t see any teachers use them. I did see some, but I didn’t even ask, because I was too busy learning stuff to teach” (interview, August 15, 2013). Other concerns involve the time spent on setting up and getting connected. A few references were made to the fact that technology can be a distraction to students and twice it was mentioned as a barrier to skill development in light of the fact that students can simply ‘Google’ answers to their questions without “think[ing] about problems anymore” (Arnold, interview, August 13, 2013).
Considerations.

The most emphasized considerations for the use of technology for teaching and learning were instructional alignment (i.e., whether the technology supports the learning outcomes) and the responsibility of the teacher to develop necessary technology-related skills in students. Science-specific technology skills noted by participants included the use of graphing applications, radar guns, temperature and humidity probes, digital pH testing devices, formulas and charts in Excel and research (i.e., online searching) skills. Other less frequently cited considerations were the cost-benefit analysis (is the use of technology worth the additional time/resources it takes to integrate) and the notion of using technology as an add-on (i.e., once the students have been ‘taught’ via direct instruction, allowing them to use technology to extend their learning). The latter point mirrors trends in orientation toward didactic instruction, discussed in findings relating to
beliefs about pedagogy in the following section: participants frequently referenced ‘teaching’ as direct instruction and student-centered instruction (or in this case, student-centered use of technology) as something else. Andrea conveys this notion of ‘something else’ in her explanation:

I’m still a firm believer that the original content needs to be direct instruction. I think students need that grounding before letting them do Internet study research and things like that. I think there’s a time and place for everything. I would like to teach so that they get the grounded information first and then proceed further.

(interview, August 19, 2013)

Beliefs regarding pedagogy.

Conception of learning.

When asked ‘What is learning?, half of the total responses indicated an inability to clearly explicate a personal conception of learning. For example, when asked “What does learning mean to you? What happens in the process of learning – how do I know if I’ve learned something?”, Briana’s response was “I have to think about this so I don’t use the word ‘learning’…ummm…I guess when you get taught new things or you find out something you didn’t know before.” To probe the issue further, she was asked “So what do you think happens when we learn – how do I know if I’ve learned something?”, to which she responded “Umm…I’m not sure. I guess you kind of go ‘Oh I didn’t know that before’” (interview, August 2, 2013). Examining this half more closely, 21% of the references were direct statements that the participant was unable to define the concept, while 29% of such responses resulted in a general reference to ‘understanding or
knowing something new’. Prior knowledge was cited in 17% of the references as a prerequisite to learning. Both the generic ‘understanding or knowing something new’ and ‘prior knowledge’ statements (accounting for 46% of all references) indicate a perspective of learning as acquisition, while the remaining 33% of references (to applied, 13%; experiential, 12%; contextual, 4%; and inquiry-based, 4% characteristics of learning) indicate a more participatory perspective.

**Teacher role.**

When asked about the teacher’s role, 53% of references indicated the need for the teacher to act as a motivator, while 29% indicated a role as a facilitator or guide, 14% as a director, and 4% as a mentor. While these responses seem to skew toward a student-centered approach to learning, responses regarding the student’s role are somewhat conflicting.

**Student role.**

The most common reference to the students was as a ‘willing participant’; this is not necessarily a passive stance, though not one that indicates a great deal of initiative from the student. To clarify, Arnold’s quote falls into the ‘willing participant’ category: “So, the role of the student is actually giving the teacher a chance to allow them be to engaged” (interview, August 13, 2013) as does Brooke’s: “I guess to be interactive in the classroom. While they might not want to be there, just to participate anyway” (interview, August 8, 2013). Such statements do not necessarily indicate a great deal of motivation or self-directedness from the student, but they do indicate that the student’s role includes involvement. Conversely, 17% of references indicated the student’s role as one of a
‘follower’ (i.e., “To take on the information”, as stated by Jenna in her interview, August 12, 2013). Janice explains, “I think there is a role for them. I guess in the least, if they’re open. Even if they don’t have a lot of knowledge or care…if they can at least be open and quiet. Because if they’re doing something else, it’s very hard to redirect what they’re doing. So they do have a role and part of that is being polite” (interview, August 15, 2013). An equal 17% of responses indicated that the participant did not have a well-formed conception of the student role. The most infrequent response, accounting for 11% of references indicated that the student should direct their own learning.

**Teacher-student relationship.**

Interestingly, when questioned about the teacher-student relationship, 60% of responses indicated a team scenario (e.g., Drew noted in his interview, August 19, 2013 “…I think there’s a responsibility there on both parties to sort of come up with a situation that’s conducive to learning”), while 30% of references were teacher-centered and 10% were student-driven relationships.

**Orientation.**

Pedagogical orientation proved to be a messy variable in regard to expressed versus enacted values among participants. At times, this may have been due to falsely equating the teacher-as-facilitator and teacher-as-motivator roles, as demonstrated in Janice’s explanation:

One is to facilitate the learning of the students, but then you have to get them engaged in it and wanting to learn the thing that you’re going to teach them. So I think a big thing is to show the need or the relevance, the importance, to motivate
them, or just to make it interesting to them. And if you can’t do that, you can’t teach them. So you’ve got to know it enough yourself – even though I don’t think you’ve got to be an expert – there’s stuff that I’ve just learnt and then taught it to them, and sometimes I think that’s useful because I think “I had the same question.” And then they might ask a question that you didn’t think of and you have to look it up, and so I’m happy to be the facilitator and not the expert. Definitely if you’re not there making it interesting – even if it’s completely irrelevant to them – if they see the fun in it or they see fascination in it, then I think that’s a very big part of your role. I guess the other part is to show them how much they’ve learned and ways that they can use that because then you can make it relevant even if it didn’t seem relevant in the beginning. (interview, August 15, 2013)

While certainly one can act as both a facilitator and motivator, in this instance, it seems these roles are erroneously perceived to be synonymous. Whereas, the motivational evidence is clear, the example of a student asking a question and the teacher looking it up (even if after stating that they don’t know the answer) to inform the student appears to be a more teacher-centered approach than a facilitator role might indicate. After being asked to explain science herself, Ellie was asked “How would you help a secondary student conceptualize science?” In explaining her approach, she first focused on tactics she would employ to capture student attention before explaining (via direct instruction) the importance of inquiry in science:
...so really interesting, disgusting facts, you know, and even the older kids love that. And silly songs about the periodic table. So I think initially, it’s capturing their attention. I also like adding in the historical aspects. So once upon a time, we all thought the world was flat and boats were going to fall off the end – I haven’t used that one, but that type of thing where you tell them something we used to believe, because that’s all we knew, and it’s fascinating to think ‘why the heck would they think that?’ and then you say ‘well the only way they discovered it was blah blah blah blah, and now we know this and it was because of this person or this woman, and they found this, and this is how they found it because they were curious.’ So I think it’s important to show them how people discovered things through their curiosity and their application of the scientific way and to explain what the scientific way is in the most basic form. (interview, July 31, 2013)

While the employment of a transmission-of-knowledge approach to helping students understand and appreciate inquiry may seem ironically misaligned, this disconnect is not unfounded in terms of what has been modeled through educational experiences (see Table 12 and Modeling TPACK in the university context for further discussion). While participants tended to extol student-centered approaches, there was a disconnect in the way they often talked about ‘teaching’ and ‘learning’ as inherently didactic and as prerequisite to student-centered activities, which often did not seem to fit into these categories, but rather seemed to be something else. Table 8 includes statements that exemplify this perspective. Hannah and Drew refer to the notion of prerequisite
didactic teaching when broaching new topics with students; Ellie, in recalling an effective teaching experience from a student perspective, eludes to the notion that ‘teaching’ and ‘learning’ occur didactically, while activities are something ‘else’, and Jenna explains that if time allows, her lessons will include activities, but if there is a lot of content to cover, the priority will be to ‘get it through’ to students (Table 8). Abby, reflecting on a terrible learning experience, actually recalled how greatly she disliked textbook lessons as a student, while indicating that they are a necessity to learning science, again referring to the need to ‘learn’ first before doing anything else (Table 8).

Table 8
On a Didactic Prerequisite to Teaching and Learning

<table>
<thead>
<tr>
<th>Participant</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hannah</td>
<td>I think unfortunately in science, there’s a certain level where you just need to learn it – it just needs to be kind of…sure you can maybe employ games, but…I keep coming back to terminology, but for example, that sort of thing, or like you can’t put together the respiratory system until you learn each part of it, so you need to sort of get those foundations, and sometimes I think that is done in a boring way or in a direct kind of rote learning way, which I know is kind of like a swear word in current teaching, but then once you’ve got that, I think that’s when you can start doing things…yeah, so I think those sort of foundational things or those more concrete things are going to lend themselves to being more direct or old school kind of things, and then as things get more interesting, you can use different things more effectively. (interview, August 13, 2013)</td>
</tr>
<tr>
<td>Abby</td>
<td>[Researcher: Can you think of a really terrible learning experience that made you think ‘I never ever want to teach this way?’] Textbook lesson – textbook lesson, definitely. It’s so horrible – the whole time just 70 minutes just writing down in my text. I’m one of those people that really hates it when teachers say ‘No textbook</td>
</tr>
</tbody>
</table>
Beliefs regarding content.

The question ‘What is science?’ was included in the interview protocol, as participants were asked to explain their conceptualization of their content area. The majority of participants (68%) were unable to clearly define the construct with comprehensible parameters. In total, 37% of references indicate, without expounding, that ‘science is everything’ (e.g., Andrea, in her interview August 19, 2013, explained “Science is everything around us, whether it’s living things, nonliving things – it’s just everything” and Connie, interviewed August 5, 2013, stated “Science is everything – I
tell my children this all the time. It’s a part of everything around us and everything we do, and I like there to be answers and reasons.”) or that it is the ‘understanding of everything’ (e.g., Jenna, interviewed August 12, 2013, said “I guess science is the world of knowledge of everything – plants, animals, us, where we live I suppose. Just anything that we want to know about basically is related to science” and Kylie, interviewed August 7, 2013, simply stated it is the “Understanding of everything.”), while Ellie indicated that it is everything we do not understand: “Everything that we don’t understand yet that’s not – that’s like – we can actually – explain it properly – have evidence for it” (interview, July 31, 2013). The remaining explanations categorized as ‘unable to define’ included three iterations (16% of total references) of what science is not (e.g., Arnold, interviewed August 13, 2013, notes that “It’s not always provable – there’s a lot of things that aren’t provable”) and three (16% of total references) direct statements that the participant did not know.

Three definitions (16% of total) referenced an empirical aspect to science (e.g., “For me, science can be anything that’s inquiry-driven and using scientific method where you’re trying to get some type of new understanding. And I would stress the need for adherence to proper method and to make sure you don’t have bias and all of that stuff that some people I found were certainly overlooking,” Drew, interview, August 13, 2013). The remaining three references explained science as ‘how things work’ (e.g., Briana indicated science is “How things work…how things function…”, interview, August 12, 2013).
Research Question 2

What are the levels of self-efficacy of the preservice teacher candidates regarding TPACK and what experiences are shaping these?

Findings regarding participants’ general self-efficacy levels for TPACK knowledge forms are derived from survey data. Interview data was coded for high, moderate and low levels of self-efficacy and cross-referenced with TPACK and context to address the second part of the research question (i.e., what experiences are shaping self-efficacy levels?). Statements that clearly reflected levels of self-efficacy were coded, and when statements were somewhat ambiguous, the participant probing questions were employed to ascertain the level of self-efficacy participants held for various facets of TPACK. For example, Drew relays various levels of self-efficacy in the following statement (coding in parentheses):

Well, I would say my content I’m confident in from my first degree (high CK); my pedagogy I’m somewhat confident in from the Grad Dip and I think I’ll improve markedly with experience (moderate PK), but with technology I certainly had no required formal training – I’m aware that there were opportunities to involve ourselves in workshops during the course of the GradDip, but I wouldn’t say they were pushed particularly heavily…I would openly suggest that some type of technology training would be a hugely welcome addition to that program (low TK). (interview, August 13, 2013)

It is possible that self-efficacy levels for various facets of TPACK could vary depending on the specific focus. In such instances, statements were not ‘averaged’ for an overall
self-efficacy level, but coded accurately according to the level of self-efficacy expressed by the participant for the topic at hand. For example, Abby conveyed a high level of self-efficacy for her knowledge of chemistry and how to teach it:

In chemistry, I have quite a broad knowledge – I can relate it to real life because I know the content and I’ve expanded on that – I know ways it can be applied to real life. I can just do that – it’s more natural. (interview, August 8, 2013)

Conversely, she expressed a low level of self-efficacy for teaching physics, saying “…if I walked into the school and they said ‘OK – you’re teaching physics’, I’d be like ‘Aaaaaaaaaaaa I’m gonna have a heart attack’” (interview, August 8, 2013). The former statement was coded as high self-efficacy for CK and PCK, and the latter was coded as low self-efficacy for CK (as she was directly responding to a question about her content knowledge) and PCK. It was important to be precise with coding individual assertions rather than attempting to assess an ‘overall’ or ‘average’ self-efficacy level with interview data, as later questions uncovered related experiences that were coded and cross-referenced to determine sources of self-efficacy for various facets of TPACK.

**Self-efficacy for TPACK.**

The Survey of Preservice Teachers’ Knowledge of Teaching and Technology was employed to gather self-reported data on participants’ levels of self-efficacy for TPACK and its components. Participants responded to Likert-type scale items regarding self-efficacy for TPACK, indicating their agreement (1 = *Strongly Disagree*, 2 = *Disagree*, 3 = *Neither Agree nor Disagree*, 4 = *Agree*, 5 = *Strongly Agree*).
Participants reported the highest level of self-efficacy for content knowledge ($M = 3.64$), with no participant indicating a score below a neutral response. All solitary forms of knowledge were ranked highest for self-efficacy: pedagogical knowledge with a mean of 3.65 and technological knowledge with a nearly equal mean of 3.64. Of the remaining forms of knowledge, dual-components PCK and TPK ranked highest with nearly equal means of 3.42 and 3.41, respectively, followed by TPACK. Technological content knowledge, or the knowledge of technologies for science in this case, ranked the lowest in terms of participant self-efficacy. As Kylie indicated in her interview, the straightforwardness of content knowledge may make it easier to grasp, followed by other single-component knowledge forms (i.e., technological knowledge and pedagogical knowledge), but difficulties arise (yielding reduced self-efficacy) in effectively pairing these forms of knowledge without much experience or guidance on how to do so: “That’s why I’m strongest in content - because it’s very clear and defined, and then the technologies and strategies - I need to find the link and connect them up somehow without the strongest knowledge base to do so” (interview, August 7, 2013).

Table 9
*Characteristics for Scale Scores (N=12)*

<table>
<thead>
<tr>
<th>Scale</th>
<th>$M$</th>
<th>$SD$</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content Knowledge (CK)</td>
<td>4.22</td>
<td>.59</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Pedagogical Knowledge (PK)</td>
<td>3.65</td>
<td>.74</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Technology Knowledge (TK)</td>
<td>3.64</td>
<td>.77</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Pedagogical Content Knowledge (PCK)</td>
<td>3.42</td>
<td>.67</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Technological Pedagogical Knowledge (TPK)</td>
<td>3.41</td>
<td>.79</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Technological Pedagogical Content Knowledge (TPACK)</td>
<td>3.33</td>
<td>.78</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Technological Content Knowledge (TCK)</td>
<td>3.25</td>
<td>.97</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

*Note.* Ratings based on a 5-point metric, 1 = Strongly Disagree to 5 = Strongly Agree.
Context-specific experiences shaping TPACK self-efficacy.

Interview data was coded for references to low, moderate and high self-efficacy levels of TPACK and its components. These references were queried against context in order to determine what experiences (i.e., what contexts) are shaping participants’ self-efficacy for TPACK. For example, a participant may relay a successful teaching experience in prac yielded a sense of high self-efficacy for pedagogical content knowledge or they may report a negative experience in an informal learning context that they felt led to a low sense of self-efficacy for technology.

By context.

Pedagogical content knowledge was the most frequently referenced knowledge type throughout interviews. Most cited were references to experiences within the university context (see Figure 4). The university context was the most frequently cited context attributing to self-efficacy levels for PCK (see Figures 5 and 6). Figures 4-6 maintain consistent vertical axis scales for comparison purposes. Much of the attributions to university for low self-efficacy levels concern a lack of experience teaching (or learning to teach) science (PCK), (e.g., Janice indicated, “I haven’t learned how to teach science”, interview, August 15, 2013; Briana noted, “It’s been very hard for me to think about ‘how would I use that in science?’ I’m struggling to draw it all in together”, interview, August 2, 2013; and Connie explained, “there needed to be a subject that said ‘this is how you teach science’”, interview, August 5, 2013). The university context is also the most frequently attributed for high self-efficacy levels, particularly for PCK and CK. Within the university context, prac (i.e., student teaching or field experience) is not
cited as a source of high levels of self-efficacy for any component of TPACK; it is cited for every component but TCK for moderate levels of self-efficacy and is attributed to low levels of self-efficacy for content knowledge, pedagogical knowledge and TPACK. School experience (i.e., Pre-12) is cited as a source of high self-efficacy for CK and TK, moderate levels of self-efficacy for PCK, TCK, TPACK and TPK, and low levels of self-efficacy for CK. The informal educational context is the greatest source cited for high self-efficacy for TK and is also attributed to PK and CK.

Figure 4. Low self-efficacy references by context.
Figure 5. Moderate self-efficacy references by context.

Figure 6. High self-efficacy references by context.
By TPACK component.

Participants reported highest levels of self-efficacy for content knowledge (CK) via the survey. Experiences in university and school contexts were most frequently attributed to high levels of self-efficacy for content (see Figure 7).

![Figure 7](image_url)

*Figure 7. Self-efficacy references to content knowledge by context.*

After content knowledge, pedagogical knowledge (PK) was ranked highest for self-efficacy by participants on the survey. The highest self-efficacy levels for pedagogical knowledge were attributed to informal educational experience and intuition, while university and prac experience were cited for yielding moderate levels of self-efficacy. Informal educational experiences were the only context cited for yielding low levels of self-efficacy for PK (see Figure 8).
Self-efficacy levels for technological knowledge were practically the same as those for pedagogical knowledge. Informal educational experiences were the most frequently cited source of high levels of self-efficacy for TK, followed by school experiences; the university was the most frequently cited context associated with low levels of self-efficacy for TK (see Figure 9).

Figure 8. Self-efficacy references to pedagogical knowledge by context.

Figure 9. Self-efficacy references to technological knowledge by context.
The university context was by far the most frequently cited for experiences impacting PCK self-efficacy, with 11 references to this context tied to low self-efficacy, 4 tied to moderate and 7 tied to high levels of self-efficacy (see Figure 10). The majority of the limited references to prac experience as tied to PCK indicated this context as a source of low self-efficacy.

Figure 10. Self-efficacy references to pedagogical knowledge by context.

TPK at all levels of self-efficacy was attributed equally to the university context, while moderate levels were cited once within a prac experience and within the context of school (see Figure 11).
Figure 11. Self-efficacy references to technological pedagogical knowledge by context.

The most frequently cited context for sources of TPACK self-efficacy was the university context, with the majority of experience being attributed to low self-efficacy levels (see Figure 12). Teaching experience as well as prac were also cited for low levels of self-efficacy for TPACK.
Self-efficacy levels for TCK were the lowest, as reported via the survey. TCK was the least frequently referenced component of TPACK throughout interviews. Both the university and school contexts were cited once as sources for moderate and high levels of self-efficacy for TCK (see Figure 13).

**Figure 13.** Self-efficacy references to technological content knowledge.
**Impacts of self-efficacy in planning for instruction.**

Interview data indicated various impacts of self-efficacy for instructional planning (see Table 10). One trend was that self-efficacy for content knowledge impacts pedagogical plans for instructions. Specifically, the lower the self-efficacy levels for content, the more didactic instruction will become. Relatedly, lower teacher self-efficacy levels for content may also yield less authentic learning experiences for students. Self-efficacy levels for content may also impact plans for technology. Self-efficacy levels for technology are likely to influence plans for technology use in instruction.

### Table 10

<table>
<thead>
<tr>
<th>Relationship</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-efficacy for content impacts pedagogy</td>
<td>I guess in chemistry, not knowing, I would use a lot more structured, very simple, I guess, because I would be learning too while they were learning…so PowerPoint’s probably going to be the best option for what I learned – putting that into a PowerPoint and then retelling it to them. [Researcher: So more transmission of information?] Yeah. And then biology, I guess I’d just run activities around what I know. I wouldn’t have to go out and research an awful lot to know what to teach them. [Researcher: So more hands-on and interactive?] Yeah. (Jenna, interview, August 12, 2013)</td>
</tr>
<tr>
<td>When I was doing cell structure I was more relaxed and could talk to them and check if everyone understands. I was more laid back and making sure they were following properly, but when I was teaching something I wasn’t really familiar with, I’d go through it dot by dot and I’d forget to check if they were understanding. So I had some problems with the natural selection – I had to do this big summary sheet for them. I was more stressed about whether</td>
<td></td>
</tr>
</tbody>
</table>
I was explaining it to them right instead of worrying about whether they were getting it. (Ellie, interview, August, 2013)

The subject that I’m confident with would definitely allow more opportunities for questioning and to just experience the topic more, whereas the subject I’m less confident with would be very regimented I suppose, which is not a good idea – that’s playing it safe for me because I wouldn’t want to be stuck in a situation where they’re like ‘hey – why is this?’ and I’d be like ‘I have no idea.’ (Brooke, interview, August 8, 2013)

I did a revision lesson with the rocks, so I made that very engaging because I was very confident with the knowledge I had. We had some games because one of the pieces of their exam was that they had to read information off a table. So I gave them all that table and played celebrity heads. …then when I went on to the mining stuff [with which she previously indicated she was not familiar], one of the substitutes I had said it was much of the same thing just shown in a different way, so it wasn’t a great deal of variety or depth. [Researcher: So it was just more you presenting the content?] Definitely. (Kylie, interview, August, 2013)

So I think in terms of pedagogy, to try authentic learning and involving students and all that sort of stuff – if you’re really confident in what you’re teaching, it’s a lot easier because if they start straying, you can bring them back or you can link it to different ideas that they might be more confident with, and you can draw on different things; whereas when you’re not confident, you’re almost trying to stick to a script because if they go outside of that, you’re going to have to be like ‘I don’t know.’ [Researcher: So do you think with things you’re less confident with, it would be more direct instruction?] I think so for me. Or using pre-prepared resources or relying on other things more than your own plans. (Hannah, interview, August 13, 2013)
Table 10: continued

<table>
<thead>
<tr>
<th>Relationship</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relationship</td>
<td>In chemistry, I have quite a broad knowledge – I can relate it to real life because I know the content and I’ve expanded on that – I know ways it can be applied to real life. I can just do that – it’s more natural. Physics would be a much more textbook approach. I would be teaching out of the textbook because the textbook knows what it’s talking about and I don’t. So my students would definitely be at a disadvantage because I wouldn’t be able to show them something a more experienced physics teacher would be able to (i.e., this is how it relates to real life). (Abby, interview, August 8, 2013)</td>
</tr>
<tr>
<td>Self-efficacy for content impacts technology</td>
<td>I think your level of knowledge would impact the ability to access certain interactive resources, so you’re gonna know where to look with things that you know for things you could use. I think I would aim to make both lessons as interesting as possible, but it’d be a lot easier with what I’m more familiar with. (Drew, interview, August 12, 2013)</td>
</tr>
<tr>
<td>Self-efficacy for technology impacts use of technology</td>
<td>[Researcher: Can you talk through the process of planning a science lesson and how you would decide whether to use technology and if so, what technology to use?] Obviously, my ability to use it. I’m not too inclined to use something if I can’t do it myself. So that’s a big factor. (Connie, interview, August 5, 2013)</td>
</tr>
<tr>
<td>Self-efficacy for technology impacts use of technology</td>
<td>I think I’m comfortable with the idea of [using new technologies], and I guess I just want to make sure that I know how to…when things go wrong, you don’t start feeling like a deer in the headlights. (Hannah, interview, August 13, 2013) And the other thing is how well I’m able to run it myself. If I can’t work it, there’s no point in asking them to because they’re going to ask me how and I’ll be like ‘I don’t know!’ (Kylie, interview, August 7, 2013)</td>
</tr>
<tr>
<td>Self-efficacy for technology impacts use of technology</td>
<td>…I’m really behind on the whole technology thing. I just steer clear of that. (Brooke, interview, August 8, 2013)</td>
</tr>
</tbody>
</table>

...
Research Question 3

To what extent has TPACK been developed through experiences in the secondary science teacher preparation program?

Findings related to this question are the results of the analysis of interview data, coded for TPACK components and university-specific contexts included in the secondary science teacher preparation program. This is supplemented with selected items from the survey that elicit information regarding the modeling of TPACK in various contexts within the program (e.g., by education, ICT and science lecturers, other lecturers, and mentor teachers).

Table 11 shows total references to TPACK within the university context. Both TK and CK are broken down into Grad Dip and undergraduate groups. TPACK experiences (positive, negative, and references to missed opportunities) will be explored further in the following sections.
Table 11

TPACK References in University Contexts

<table>
<thead>
<tr>
<th>Reference</th>
<th>Edu Courses</th>
<th>Prac</th>
<th>Program</th>
<th>Science Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>TK+</td>
<td>9 (8/1)</td>
<td>3 (2/1)</td>
<td>2 (1/1)</td>
<td>0</td>
</tr>
<tr>
<td>TK-</td>
<td>3 (2/1)</td>
<td>2 (0/2)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TK lacking</td>
<td>11 (5/6)</td>
<td>4 (1/3)</td>
<td>8 (2/6)</td>
<td>1 (1/0)</td>
</tr>
<tr>
<td>CK+</td>
<td>0</td>
<td>3 (1/2)</td>
<td>5 (4/1)</td>
<td>8 (8/0)</td>
</tr>
<tr>
<td>CK-</td>
<td>0</td>
<td>1 (0/1)</td>
<td>0</td>
<td>1 (1/0)</td>
</tr>
<tr>
<td>CK lacking</td>
<td>2 (0/2)</td>
<td>2 (0/2)</td>
<td>5 (1/4)</td>
<td>0</td>
</tr>
<tr>
<td>PK +</td>
<td>18</td>
<td>7</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>PK –</td>
<td>10</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PK lacking</td>
<td>7</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PCK +</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>PCK –</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>PCK lacking</td>
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<td>3</td>
<td>19</td>
<td>2</td>
</tr>
<tr>
<td>TCK +</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TCK –</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TCK lacking</td>
<td>4</td>
<td>1</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>TPK +</td>
<td>7</td>
<td>6</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>TPK –</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>TPK lacking</td>
<td>18</td>
<td>6</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>TPACK +</td>
<td>4</td>
<td>6</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>TPACK –</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>TPACK lacking</td>
<td>14</td>
<td>9</td>
<td>22</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: Grad Dip and undergraduate references to TK and CK are reported as (Undergraduate/Grad Dip) after the total.

Positive TPACK experiences.

References to positive TPACK-related experiences within the university context highlight prac experience as the most multi-faceted aspect of the program in terms of TPACK. Of all university contexts, including education courses, prac experience, references to the program in general and science courses, prac experience was the only context in which all components of TPACK were positively experienced among the sample. References to the secondary teacher education program in general encompassed
six out of seven components (with the exclusion of TCK); education courses included five out of seven (excluding CK and TCK), and science courses included four types of TPACK-related experiences (with the exclusion of TK, TCK and PK).

Throughout university experiences, there is a strong emphasis on pedagogical knowledge, particularly in education courses, the teacher education program in general and prac experience in schools (see Figure 14). The most frequently cited positive PK-related experiences included a focus on classroom management. Of 11 positive references to PK in the university context, five of them were in reference to learning effective behavior management strategies. Classroom management seemed to be a concern among participants and experiences in which they learned techniques to assist with this were highly valued. Such strategies were some of the most likely to be directly utilized in participants’ teaching experiences:

So that was really good and since then I’ve noticed myself adapting my style to help try and meet what was proven to help with behavior management. So I did make a conscious change in relation to that, and I think it did help me, especially as my pracs got longer and issues became bigger. (Kylie, interview, August 7, 2013)

The need to assess prior knowledge was also referenced in more than a quarter of these positive PK citations and translated into plans for teaching among participants. Two participants described plans for ‘assessing prior knowledge’ as part of their lessons, and when asked about what experience(s) informed their rationale for and approach to doing so, they indicated that it was frequently addressed as a critical step: “They definitely tell
you a lot to do that” (Hannah, interview, August 13, 2013); “It’s drilled into us at uni.
You must assess their prior knowledge – there’s no point in teaching them if you don’t
know that they’re going to understand what you’re saying” (Abby, interview, August 8,
2013).

Figure 14. Positive TPACK-related experiences in university context. The presence (or
absence) and size of the circles provide a precise visual indication of how frequently
participants referenced TPACK-related experiences within the context.

Education courses are also the greatest source of technological knowledge cited
within the university context, though it should be noted that there is a significant
difference between Grad Dip and undergraduate participants in reported experiences
relating to TK (see Figure 15). While the majority of references to TK-related
experiences within education courses include actual positive (8) and negative (2) learning
experiences among undergraduate participants, participants from the Grad Dip group
mainly referenced missed opportunities (6), or experiences which were lacking TK in
education courses and the secondary teacher preparation program. One likely cause of this is the inclusion of an ICT course in the undergraduate but not the Grad Dip program.

![Figure 15. Grad Dip and undergraduate TK references by university context.](image)

While PK was the most prominent component of TPACK in terms of positive experiences within the university context, it is completely lacking throughout references to participants’ experience in science courses. This context is also one in which a significant difference was found between Grad Dip and undergraduate groups, as the most frequently referenced university context for content knowledge was science courses, and these references were solely from undergraduate participants (see Figure 16). The majority of references to CK-related experiences from the Grad Dip group were to missed opportunities or experiences that were lacking CK in the university context. This
is likely due to the fact that while the undergraduate program includes a minimum of 7
discipline-specific (i.e., science) courses, no such courses are included in the Grad Dip.

Figure 16. Grad Dip and undergraduate CK references by university context.

**Negative TPACK experiences.**

References to negative TPACK-related experiences within the university context
show the majority of PK-related experiences upon which participants draw are occurring
in education courses and prac experience within the university context (see Figure 17). It
is important to remember that even though these are negative TPACK-related
experiences, they are nevertheless informing and shaping TPACK. For instance, Hannah
noted, in discussing some of her PK-related experiences at the university, that “delivering
is such a uni kind of word where you’re just talking at people rather than involving them”
(interview, August 13, 2013) – while she discussed the ‘delivery’ approach as a negative PK experience in the university context, this experience still shapes her pedagogical knowledge, as she reflects on the importance of ‘involving’ the learner. Janice noted the significance of negative experiences, as she reflected on the need to underscore learning with a rationale:

Researcher: Is this something you’ve been taught explicitly or is it something you’ve experienced as a learner or both?

Janice: Yeah, well I think more importantly, what I’ve experienced. I’ve sat in lectures and gone to sleep – the strength of it comes from my experiences when I think ‘Why? Why do you want me to know this?’ (interview, August 15, 2013)

In this example, Janice reflects upon her negative PK-related experience in order to inform her understanding of a pedagogical consideration (i.e., tying learning to an authentic context in order to make it meaningful to students).
Figure 17. Negative TPACK-related experiences in university context. The presence (or absence) and size of the circles provide a precise visual indication of how frequently participants referenced TPACK-related experiences within the context.

Combined TPACK experiences.

TPACK-related experiences were attributed to four different contexts within the university, including education courses, prac experience, references to the secondary teacher education program in as a whole and science courses. In examining the data visualizations for both positive and negative TPACK-experiences, it becomes clear that the prac experience is the most multi-faceted and complete in terms of TPACK development (see Figure 18). This context hits all components of TPACK, and was cited as including both positive and negative experiences for all facets but negative TCK experience. While the prac experience is mainly positive overall, the greatest number of references to this context are actually negative PK experiences, or incidents where participants felt the pedagogical knowledge being modeled was either lacking or contrary to what they felt was a positive, effective approach to teaching or that their own employment of PK failed. Conversely, both the education courses and references to
program-wide experiences were the largest contributors of positive PK experiences, and these experiences were the most frequently cited for each of these contexts. Second only to positive PK are negative PK experiences in education courses. Both education courses and prac experiences are the leading contributors of positive TPK experience within the uni context.

Figure 18. Positive and negative TPACK-related experiences in university context. The presence (or absence) and size of the circles provide a precise visual indication of how frequently participants referenced TPACK-related experiences within the context.

Figure 19 provides a consolidated perspective of all positive and negative references to TPACK within university contexts. It is easy to see here that the overwhelming majority of experiences that participants draw upon from their time at the university involve PK. PCK is present, though in far less frequently cited experiences than PK, across all university contexts. TPK is also cited across all contexts and is actually the second most frequently mentioned experience (tied with PCK and TPACK) within the prac context and third most frequently referenced experience in education courses.
Education courses were not referenced once for any type of CK experience, and even in prac, CK experiences are not particularly prevalent. The majority of CK-related experiences within the university context are attributed to science courses and the program in general (most likely to the science content courses within the program). It is important to note that CK is one of the two TPACK components for which a significant difference exists between Grad Dip and undergraduate participants. Preservice secondary science teachers in the Grad Dip program do not take science courses, leaving education courses and prac as their only opportunities for CK-related experiences within the university context. Drew, a participant who had just finished the Grad Dip program, discussed the absence of content courses (and experiences with related knowledge types) within the program:

Researcher: Are there any other experiences from the GradDip program that you’ve drawn on to help you teach science?

Drew: I don’t really know if you’re aware, but in the GradDip program that I’ve just done, it’s I guess what you would call all pedagogy. There’s no subjects that
are actually content knowledge or that develop curriculum materials or anything like that. So I guess from a pedagogical point of view, I’m sure that there are some things that we did that are useful. I mean, they’re the backbone of what I do I guess, but from a scientific point of view, I think it’s interesting to me that the degree is structured that way – that there’s no specific sort of content instruction. Just remind me again what the question is…

Researcher: Are there any experiences from the GradDip program that you’ve drawn on to help you teach science?

Drew: Umm…from the degree…I’m drawing a bit of a blank to be honest. (interview, August 12, 2013)

Connie, another participant who had just completed the Grad Dip program and started a high school teaching position, noted strong focus on PK in the program:

Because the Grad Dip is like ‘here’s a quick look at teaching’, but you’re relying on your previous degrees for content knowledge…as a high school teacher – it’s really interesting…the behavior management stuff I did on the Grad Dip I use all the time or even those books – I’ve brought all those resources with me. They’re like a toolbox. (interview, August 5, 2013)

It is noteworthy that Connie seemed to value most the pedagogical experiences she gained within the university (particularly in education courses), though when she discussed plans for teaching science specifically, she relied heavily on experiences she had as a student and her own intuition and preferences for learning science.
Some of the ways they got us to plan work or plan lessons – I get what they were trying to teach us, but day-to-day, I’ll never ever do that again because I’m not going to put four hours of planning into a one-hour class. I understand what they were trying to teach us, but doing it that way is very different form the real world. I’ve known for a long time that the first 3-5 years of teaching is where you actually learn what you’re doing. (Connie, interview, August 5, 2013)

While some PCK-related experiences are most prevalent in prac, they are the least frequently cited TPACK-related experiences of all those referenced within education courses, and Grad Dip students do not benefit from the PCK experiences present in science courses. TCK is nearly absent from the university experience, with a small number of related experiences referenced only within the context of prac. TPACK, then is the only remaining knowledge type that includes content knowledge. Both prac and education courses are leading contexts in which TPACK-related experiences are cited, with fewer instances reflected in references to the program and science courses.

TK was referenced most frequently in the context of education courses, though these experiences are far more common among undergraduate participants than Grad Dip (as shown in Figure 15), likely due to the inclusion of the ICT course within the undergraduate program. Limited references to TK-related experiences are also found in prac.

**Modeling TPACK in the university context.**

Participants were asked to indicate an estimated percentage of time TPACK was modeled in university-related contexts. Responses to this item are shown in Figure 20.
Most (67%) participants indicated that lecturers in the university context modeled TPACK in half or less of all their teaching. While no one reported mentor teachers modeling TPACK most of the time, results were more evenly distributed, as one-third of participants indicated mentor teachers modeled TPACK between 51% and 75% of the time, between 26% and half of the time, and 25% of the time or less.

![Bar chart showing participant-reported frequency of TPACK modeling in university context.](image)

**Figure 20.** Participant-reported frequency of TPACK modeling in university context.

Throughout interviews with both undergraduate participants and those from the Grad Dip program, a noticeable trend to comments regarding the modeling of TPACK was an indication of a ‘teach as I say and not as I teach’ model. This disconnect is illustrated in the quotes in Table 12.
Table 12: On a the Disconnect Between Espoused and Enacted TPACK-related Values

<table>
<thead>
<tr>
<th>Participant</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ellie</td>
<td>But they’ve got a board they’ve got all these things that they could do but they just put lecture slides up and it’s just lecture slide after lecture slide...I suppose we’re expected to be able to focus ourselves, but I find it quite ironic that it’s like 'you need to be able to engage students when you’re teaching them, but here – have a lesson. Just watch it.' And you’re just like 'you’re supposed to be engaging me, aren’t you?' (interview, July 31, 2013)</td>
</tr>
<tr>
<td>Hannah</td>
<td>I mean, I think (the lecturers) say that, but maybe they don’t use it that much themselves as well. So it’s sort of like 'yeah yeah – make sure you cross all the technology' but then they’re still just on the whiteboard or still just on the PowerPoint. (interview, August 13, 2013)</td>
</tr>
<tr>
<td>Janice</td>
<td>We used a bit of technology, but not necessarily to teach. Although maybe in some of the lesson plans we had to show use of technology in a tick box maybe. I think maybe on prac our mentors might have had to tick off something to say that we used ICT I think. So we tried to make sure we did, but...there wasn’t a lot of that in (the program). (interview, August 15, 2013)</td>
</tr>
<tr>
<td>Andrea</td>
<td>...some of the education subjects are very similar. They lecture the content, which is good because we need to learn the content, but a pedagogy subject where they’re trying to teach you different ways to incorporate things into a class and different methods, but they’re still standing at the front and lecturing to us. I can give you a really good example of that: Diversity in pedagogy is supposed to be different pedagogies for diverse learners and special needs and things like that...I did it in the summer semester, so it was all external (online). They took down all of the lectures because they had conflicting dates. They didn’t re-record them so they had all the semester 1 dates on them, so they took them all down so as not to confuse us, and told us to read out of a textbook. So that was my diverse learning experience – to read out of a textbook, take notes, and then do an online quiz from the textbook. (interview, August 19, 2013)</td>
</tr>
</tbody>
</table>
Research Question 4

What sources of TPACK do preservice science teachers draw upon in planning for instruction?

Findings related to this question are the results of the analysis of interview data, coded for TPACK components and context. Codes for orientation (i.e., didactic and student-centered) were also applied to provide insight into the orientation of referenced experiences. Codes for orientation were applied to identified specific examples. This includes participants' plans for instruction as well as experiences from any context. It does not include broad philosophical statements (i.e., espoused values), but rather is more representative of actual/planned experiences (i.e. enacted values).

Statistical testing found no differences between program groups (i.e., Grad Dip and undergraduate) for any TPACK component attributed to a context beyond the university (see previous section for differences regarding university-specific experiences contributing to content knowledge and technological knowledge). A chi-square test was performed to test the null hypothesis of no association between program and orientation; no such relationship was found, X² (1, N=147) = .61, p = .44.

A total of 587 references to TPACK and its sub-components were coded across all interview transcripts. Each reference was coded as positive, negative, or lacking. Positive and negative references were coded as evaluated by the participant (i.e., from their perspective and not the researcher's); positive references are experiences participants found useful, effective, successful, while negative references are those they felt were ineffective or detrimental to their learning. References coded as lacking are instances
where the participant cited a missed opportunity for TPACK to have been shaped/formed. Whereas, both positive and negative experiences shape TPACK, lacking experiences represent missed opportunities. Figure 21 shows the breakdown of these references across all contexts (i.e., university and beyond). TPACK-related experiences (i.e., positive and negative) outnumber references to missed opportunities greatly in PK, CK, and PCK. Though references to TK experiences outnumber those of missed opportunities, the references to experiences lacking TK account for 40% of all of those cited. For all other components that include technological knowledge (i.e., TPK, TCK and TPACK), references to missed opportunities outnumber both positive and negative references combined.

Figure 21. TPACK references across all contexts (positive, negative and lacking).
Table 13 shows total references to TPACK outside of the university context.

TPACK experiences (positive, negative, and references to missed opportunities) will be explored further in the following sections.

Table 13
TPACK References in Contexts Beyond the University

<table>
<thead>
<tr>
<th>Reference</th>
<th>Informal</th>
<th>Intuition</th>
<th>NT Work</th>
<th>Teaching</th>
<th>Pre-12</th>
<th>Tertiary</th>
</tr>
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<tbody>
<tr>
<td>TK+</td>
<td>22</td>
<td>0</td>
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<td>0</td>
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<td>CK lacking</td>
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</tr>
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<td>0</td>
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<tr>
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<tr>
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<td>3</td>
</tr>
<tr>
<td>TPACK +</td>
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<td>4</td>
<td>1</td>
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<td>TPACK lacking</td>
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<td>0</td>
<td>0</td>
<td>2</td>
<td>10</td>
<td>3</td>
</tr>
</tbody>
</table>

Note. Informal indicates informal learning experiences; Intuition includes personal preferences; NT Work includes any work-related experiences that are not teaching; Teaching refers to any non-prac teaching experiences; Pre-12 includes any references to school experience as a student; Tertiary includes only previous university experience that may have occurred prior to the teacher education program.
Positive TPACK experiences.

References to TPACK-related experiences clearly reflect a great deal of positive experience within the university context, school (i.e., pre-12) and with informal learning, as all of these contexts include every component of TPACK (see Figure 22). It should be noted that most participants do not have prior teaching experience, so while this context was referenced by some, there was not an equal opportunity for all participants to draw from such experiences, and as such, the limited number of those references within this study should in no way be interpreted as an indication of the value of teaching experience as a whole. It is notable that the two most frequently referenced sources of pedagogical knowledge are the university and intuition or personal preference. While it might be assumed that the university context would be the greatest source of PK, as participants are enrolled in a teacher preparation program, the data clearly indicates that participants are relying on intuition frequently as well as experiences from their own school experience as a student. In fact, the greatest source of positive PCK-related experiences is by far their experience as students in school. The pre-12 context also received one more citation for CK-related experiences than did the university context, though it is important to keep in mind the lack of content courses in the Grad Dip program. The greatest source of positive TK-related experiences is informal learning contexts, followed by the university, and the greatest source for positive TPK is by far the university context.
Figure 22. Positive TPACK-related experiences across all contexts. The presence (or absence) and size of the circles provide a precise visual indication of how frequently participants referenced TPACK-related experiences within the context.
Negative TPACK experiences.

In terms of negative TPACK-related experiences, PK remains the most frequently cited form of TPACK-related knowledge in the university context, though references to negative PCK become the second most cited, as opposed to being the sixth most frequent positive TPACK-related reference in this context (see Figure 23). Negative PK- and PCK-related experiences are also the most common in the pre-12 context. TCK is the only TPACK-related experience for which no negative experiences were referenced in any context.
Figure 23. Negative TPACK-related experiences across all contexts. The presence (or absence) and size of the circles provide a precise visual indication of how frequently participants referenced TPACK-related experiences within the context.

**Combined TPACK experiences.**

In examining the data visualizations for both positive and negative TPACK-experiences across all contexts, the university and pre-12 school contexts stand out as the most complete and complex in terms of positive and negative experiences shaping
participant TPACK (see Figure 24). The greatest number of experiences cited for each
context is positive and positive citations outnumber negative ones for each TPACK
component.
Figure 24. Positive and negative TPACK-related experiences across all contexts. The presence (or absence) and size of the circles provide a precise visual indication of how frequently participants referenced TPACK-related experiences within the context.
A consolidated view of all TPACK-related experiences, both positive and negative, across all contexts more clearly illustrates the number of experiences from each context that have been referenced throughout interviews with participants (see Figure 25). This diagram shows contexts have provided the most memorable TPACK-related experiences upon which participants draw. These are the experiences that have shaped TPACK among the preservice secondary science teachers in this study.

It is apparent that the university context as a whole is the greatest source of TPACK for preservice teachers. While this may be as expected, it is important to note that it is not the greatest source of all TPACK-related knowledge types. The greatest source of knowledge of how to teach science (i.e., PCK) for participants in this study is their experience as pre-12 students in school. Reports of experiences related to content knowledge also indicate that the pre-12 school experience is a critical source of CK. While 22 instances of CK were cited within the university context, 19 were cited from pre-12 and 11 were cited (mostly by Grad Dip students) from previous tertiary experience. In terms of PK, 52% is shaped by university experience, though school experience (21%) and intuition, or personal preference (14%) are also significant sources. The university (39%) and informal learning experiences (35%) are the largest sources of TK, followed by the pre-12 context (12%), and well over half of all TPK is attributed to the university context. TCK is the most underdeveloped form of all TPACK types, accounting for only 4% of referenced experiences. TPACK-related experiences are contributed to the university context 44% of the time, while 23% are attributed to pre-12 school experience and 23% to informal educational experiences.
Figure 25. Consolidated TPACK-related experiences across all contexts. The presence (or absence) and size of the circles provide a precise visual indication of how frequently participants referenced TPACK-related experiences within the context.
From another perspective, when individual university-related contexts are parsed out (as in research question 3) and compared to all contexts referenced by participants, the significance of the Pre-12 school experience to the development of TPACK-related knowledge is further elucidated. Figure 26 illustrates this, and it is clear that the greatest source of TPACK-related knowledge in general is Pre-12 school experiences. In fact, 27% of all TPACK-related knowledge referenced was tied to participants’ experience as a student in Pre-12 school. Education courses were the second most frequently referenced source of TPACK-related experiences at 15%, followed closely by both informal educational experiences and prac experience, each representing 15% of all cited TPACK-related experiences. From this more detailed perspective, experiences from participants’ Pre-12 school days as students are the most frequently referenced for three TPACK-related knowledge types, including CK, PCK and TPACK, and have only one fewer reference (27) than education courses (28) for PK. That means that the preservice secondary science teachers in this study reflect more frequently upon experiences they had as students in Pre-12 school for knowledge about science, how to teach science and how to use technology to teach science than they do on any one facet of their teacher preparation program, and that they draw almost equally upon experiences from Pre-12 school and education courses for knowledge of general pedagogy.
Figure 26. Consolidated TPACK-related experiences, all contexts, university parsed. The presence (or absence) and size of the circles provide a precise visual indication of how frequently participants referenced TPACK-related experiences within the context.
Recall that there is a significant difference between the undergraduate and Grad Dip groups for CK in the university context, due to the fact that the Grad Dip program does not include science courses, as preservice teachers in this program already have a Bachelors degree in science. If the references to science courses in the university context and references to previous tertiary experiences are combined for CK, the adjusted totals show 36% of CK as related to experiences from university science courses and 34% related to participants’ Pre-12 school experience. It seems unlikely that participants actually gained greater total science knowledge in their Pre-12 school experience than in the seven university-level science courses in the undergraduate program or the completion of a science degree in the case of Grad Dip participants. The high frequency of referencing Pre-12 school as a source of content knowledge likely aligns with the relevance of the CK to participants’ future role as teachers. That is, it was in this context that they developed a great deal of secondary level science content knowledge.

**Orientation.**

Orientation was coded for experiences referenced by participants in interviews across all contexts. Figure 26 shows the number of experiential references coded for either didactic or student-centered orientation by the context in which they were situated. It is easy to see that the majority (75%) of these experiences are didactic in nature.
The experiences these preservice secondary science teachers draw upon most frequently for TPACK are those as students in education courses and during their time in school. These experiences are primarily didactic, as are those reported from prac, in which participants are observing teaching. Prac is a context in which participants have a dual role as both students of a teacher preparation program, observing a master teacher, and teachers in training, as they plan and execute their own learning activities with the class. In the teacher role, both in prac and in discussing their own intuitive approaches to teaching, orientation is overwhelmingly didactic.

**The repetition of educational history.**

Trends in interview data reflect the notion that participants often default into teaching the way they were taught. As Kylie notes
For me, it will mostly be the experience that I’ve had – when I’ve gotten more experience myself is when I believe I might start to branch out and think differently, which is why I do things the old school way – because that’s how I learnt. I learnt textbook, pen and paper without a great deal of technology.

(interview, August 7, 2013)

This notion of teaching the way one was taught persists, even when participants did not particularly appreciate the approach as a student. For instance, when asked ‘Can you think of a really terrible learning experience that made you think ‘I never ever want to teach this way?’’, Andrea’s response was “My entire high school life”, as she proceeded to explain the lack of engagement and the “mundane” process of being a student in a very teacher-centered educational system. Andrea was, however, the participant who later asserted that

I’m still a firm believer that the original content needs to be direct instruction. I think students need that grounding before letting them do Internet study research and things like that. I think there’s a time and place for everything. I would like to teach so that they get the grounded information first and then proceed further.

(interview, August 19, 2013)

Even with a strong distaste for lecture as a student, Andrea’s prior experiences with highly didactic pedagogies seem to have yielded a fairly narrow conception of teaching. While she aspires to be better than the teachers who taught her, she seems to maintain a perception that teaching is inherently didactic and that more student-centered methods must always come after direct instruction. This is similar to Abby’s reflection, in which
she responded to the same question, relaying how “horrible” textbook-based lessons were as a student, but indicating a need for this approach to teaching science (see Table 8 for quote). Likewise, Hannah’s response echoed this notion of didactic instruction as an undesirable yet unavoidable pedagogical necessity:

I think that is done in a boring way or in a direct kind of rote learning way, which I know is kind of like a swear word in current teaching, but then once you’ve got that, I think that’s when you can start doing things… (interview, August 13, 2013)

This was a clear trend among participants, in that many would reflect on their experiences as students with negativity when talking about teacher-centered approaches to instruction, and yet would cite such approaches as a compulsory to teaching science.

Not all reflections from a student perspective were negative – those that were positively referenced were typically more student-centered or, more often than not, included perhaps less instructionally relevant but memorable elements of external motivation. In instances where participants recalled positive learning experiences as students, they often relayed intent to recreate these experiences in a teacher role:

I’ve used quite a lot of [my favorite former science teacher’s] lessons so far…I sort of go ‘ok, how did I learn this?’ and I have to go back to the curriculum to see how it’s changed a little bit and put it into what I can do with these students and tailor it to the class I’m teaching. Most things I can draw on my own experiences on how I learnt it. I learnt almost everything there was in high school science, so I know everything that they’re talking about. But I have to backtrack a bit because I had a gap year and then I had a year of wildlife science so I have to think ‘I can’t
remember how I did that’. I have all my grade 12 books so I can go back into them and look at the notes I was taking. (Ellie, interview, July 31, 2013)

Notably, these instances in which participants relayed intent to recreate an experience they had as students were always in reference to the time as a student in school (often in their secondary science classes). There was no instance where a participant noted a specific experience as a student in a course within the teacher preparation program that they intended to recreate as a teacher. This may be attributable to the segregation of content and pedagogy within the program, as Ellie explained:

Researcher: So are you saying that you seem to be getting content in one piece and pedagogy in another piece?
Ellie: Yeah – because they’re two completely different faculty...So it’s silly – it’s stupid to teach ‘this is how you teach’ but then ‘you get to teach this and that’ because you know about those things, but I don’t know how to teach specifically about those things.’ Researcher: How do you reconcile that?
Ellie: I was in a panicked state during my last prac because I’m supposed to be able to grab this from there, grab this from there and put them together myself. I looked through my education textbooks to find anything science specific, and I was looking through journal article topics to see if there was some sort of way, but no – I had to come up with those different things myself. That’s when I started looking at my education in high school – because they don’t give you any new ideas here [at the university]. (interview, July 31, 2013)
For most, where participants hope to outperform their evaluation of their own former teachers is through the inclusion of more ‘fun’ or engaging activities for students (after they first ‘teach’ the necessary content or skills). Often this focus on increasing interest is erroneously equated with student-centered pedagogy, as discussed previously. However, one participant clearly indicated an awareness of such pedagogy along with a desire to understand it and be able to apply it in an authentic context. Janice reflected on this deficient knowledge:

There is something that I would love to do, but I don’t know how. They say that it would be good if you can let the students create their own learning, so they discover for themselves and you guide them and facilitate their discovery of the learning, but I don’t know how that can be done. I’ve never seen anyone do it; I’ve only seen people say ‘right, this is what I’ve got to teach them - stick it up there – this is what you’re gonna learn; this is how you’re gonna do it; here are some basic exercises, go home, and then I’ll test you.’ And I’ve heard that there’s other ways, but I haven’t seen that yet.

Researcher: So when you’ve heard about this type of teaching, was it through the Grad Dip program or just you looking for something else?

Janice: Yeah – some mothers at school – because we’re part of an independent school that teaches differently – but they’re only primary. So I guess I’d like to see ways to incorporate discovery with the standard stuff in some way. I haven’t seen it done in high school; I’ve only seen it done in the primary sector. So it’s a bit disappointing to me that that isn’t more incorporated, because to me it’s more
cutting edge, and that kind of discovery they say is more likely to be embedded in your memory because you worked it out somehow.

Researcher: So do you think that you will look for opportunities to learn about that and incorporate it in your teaching?

Janice: Yes. I guess I would just start with the basics that I’ve learnt and I’ve seen and try to make it as interesting as possible, but definitely if there’s ways to slip in a quick discovery thing. I don’t know how that would be done, because...yeah, but I’d really like that to be integrated into my strategies somehow. (interview, August 15, 2013)

Pedagogically, when participants describe plans for teaching or recount teaching experiences, the methods they employ seem to align with their previous experience as students, though motivationally, participants espouse to be more focused on students. This is reflected in not only discussions of pedagogy but in beliefs about technology as well, as the greatest perceived benefit to technology integration was its potential to increase motivation and interest (see Figure 2). Most cited affordances that provide insight into pedagogical orientation indicate a teacher-centered focus (e.g., technology for organization, either as a repository or to aid memorization; display or projection; efficiency; classroom management). While preservice teachers draw on previous experience as students for pedagogical and content-related forms of knowledge, experiences with technology for teaching and learning may be lacking:

I think I consider that I got a very good education when I was 16 to 17 with the science teachers that I had, so I would say that I draw on that, but that’s coming to
be quite a long time ago, in the scheme of technology in particular. So the sort of things that we have access to now were not possible then. But the enthusiasm, as I keep coming back to, was palpable then and is still very important now in my view. I mean it’s crazy to think that during those last couple years of my secondary schooling, we didn’t use the Internet at all. Like – not at all. I didn’t have e-mail until I was at university. (Drew, interview, August 12, 2013)

Brooke echoes this lack of TCK, TPK and TPACK-related experiences upon which to draw. When asked about experiences that have impacted her knowledge of how to use technology to teach science, she noted "I don’t really have a lot. My high school teacher did use YouTube videos every now and again, but that was really about it" (interview, August 2, 2013).

**Piecing together TPACK.**

While self-efficacy levels for single-component knowledge types CK, PK and TK are the highest of all TPACK knowledge components, participants articulate great difficulty in ‘piecing together’ these forms of knowledge to understand how to effectively employ technology to teach science (see Table 14). This evidence suggests that TPACK is not implicitly bolstered through the development of its individual components.
<table>
<thead>
<tr>
<th>Participant</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andrea</td>
<td>I find the courses are structured really well and the content is great, but they throw all of this at us, and then don’t show us ways of implementing it. So we’ve got this great pool of content, but there’s nothing really showing us how to incorporate it back...we’ve sort of got all of this knowledge floating around, but we’re really struggling with how we’re going to bring that back into the classroom. ...So for those sciences that I said earlier, I haven't done anything in the classroom with them. It’s just learning straight content...there’s no ‘how can we make science more fruitful in the schools?’ So I do struggle with that – because then you do your education-based subjects, which are focused on the education side of things, which is great, but there’s nothing putting them all together. That’s what I find the hardest. (interview, August 19, 2013)</td>
</tr>
<tr>
<td>Janice</td>
<td>I haven’t learned how to teach science. I’ve learned science, and I’ve used it in some way, shape or form, and then I’ve learned how to teach. But because I’ve done the Dip Ed, and we didn’t have any ‘How to teach science’ subjects, I haven’t really been taught how to teach science… I can’t think of anything, but maybe that’s because I haven’t learnt much in ICT. I can’t think of anything that I could teach them at the moment with ICT. (interview, August 15, 2013)</td>
</tr>
<tr>
<td>Briana</td>
<td>I don’t think there’s been technology at all. And now I’m really interested because I don’t think we will cover that much. Like it’s probably going to be an added bonus to pick up along the way. I suppose pedagogy is the focus It’s assumed that content is covered and it’s up to you to relate it to the pedagogy. It’s been very hard for me to think about ‘how would I use that in science?’ I’m struggling to draw it all in together. (interview, August 3, 2013)</td>
</tr>
<tr>
<td>Jenna</td>
<td>[Researcher: Do you see these components being integrated or are they addressed separately in terms of using technology to teach science?] Not really in science because it’s a separate part of the uni. We don’t really learn how to reteach it – we’re learning ourselves, but...basically when I was in grade 8 I was like ‘I’m going to be a teacher; I’m just going to start paying attention and thinking of how I could do this.’ But yeah, there’s a very big gap</td>
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<tr>
<td>Participant</td>
<td>Statement</td>
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<tr>
<td></td>
<td>between the two of them, and for I guess other students who don’t draw on their own knowledge of how to reinterpreted that to teach that, it will be difficult…it would be good for them to be integrated more because they’re kind of a very distant sort of thing…it’s basically learning three different degrees. (interview, August 12, 2013)</td>
</tr>
</tbody>
</table>
Chapter 5: Discussion

This study aimed to understand the experiences, and specifically in which contexts these experiences occurred, that shape preservice secondary science teachers’ TPACK. One participant described the impact of such experiences on preservice teachers:

I think when I decided to do teaching, it was very much ‘I want to be like my teacher’ or ‘I don’t want to be like that guy’ you know? You start to pull apart the good and the bad…So I think you very much do look at the experiences that you had through your previous experience, whether it be prep through twelve or uni or whatever and go ‘yes, I really liked that’ or ‘no, I don’t’ or ‘I want to include that’ or ‘I don’t want to include that.’ It can’t not affect what you do and how you see your role. (Connie, interview, August 5, 2013)

The Importance of Experience

This study has demonstrated the critical nature of experiences in the development of TPACK. There is a graphic of the TPACK model that is pervasive throughout the relevant literature (see Figure 28). It should be noted that this diagram is not intended to relay importance of any one facet over another, even though the size of components decreases as additional types of knowledge is added (i.e., solitary components TK, PK and CK are the largest circles, while dual components are smaller and TPACK is smallest in the center).
Findings from this study have been arranged to visually elucidate the TPACK-related experiences referenced by the preservice secondary science teachers in the context of their teacher preparation program (see Figure 28). Again, this diagram is not intended to prioritize any one knowledge type over another; however, it is clear that the greatest focus of experiences in the formal training of these preservice teachers is pedagogical knowledge.
Figure 29. TPACK-related experiences in preservice secondary science teacher preparation program. The size of the circles provide a precise visual indication of how frequently participants referenced TPACK-related experiences within the context.

This study found that education courses were the most frequently referenced context for experiences that shape pedagogical knowledge; however, where additional TPACK knowledge bases are underrepresented within the teacher preparation program, the preservice secondary science teachers in this study drew from other experiences to inform their TPACK-related plans for practice.

In structuring the current chapter, findings from each research question were outlined. Themes included:
RQ 1. What are the beliefs of preservice science teachers regarding technology, pedagogy and content?: focus on motivation and interest; disconnect between expressed and enacted pedagogical orientation; teaching is perceived to be inherently didactic; inability to clearly define learning and science

RQ 2. What are the levels of self-efficacy of the preservice teacher candidates regarding TPACK and what experiences are shaping these?: self-efficacy decreases as knowledge becomes more multifaceted; the university is greatest impact on self-efficacy for TPACK, but most experiences lead to low levels of self-efficacy; self-efficacy impacts instructional planning

RQ 3. To what extent has TPACK been developed through experiences in the secondary science teacher preparation program? prac is the most multi-faceted university context and only university context in which all knowledge bases were referenced positively; all technology-related forms of knowledge were referenced more frequently as lacking than present; lack of PCK-related experiences in the university context; isolation of knowledge bases in university context; insufficient modeling of TPACK throughout program

RQ 4. What sources of TPACK do preservice science teachers draw upon in planning for instruction?: lack of technology-related knowledge types persists through all contexts; majority of participants' teaching and learning experiences have been didactic; emphasis on Pre-12 school experience as greatest source of TPACK-related experiences and knowledge.
In order to synthesize these findings, themes from the study will be consolidated in this chapter, aligned with evidence, related to participants’ context-specific experiences, positioned in relevant literature and used to inform implications for teacher education. Recommendations for future research will also be presented.

**Finding 1: Defining Learning and Science**

The majority of preservice secondary science teachers in this study did not have well-formed ideas of learning or science.

As part of the interview protocol, in alignment with research question 1 (What are the beliefs of preservice science teachers regarding technology, pedagogy and content?), participants were asked to define the constructs of learning and science (separately) in their own words. The intent was not to evaluate their responses for accuracy or to judge them against any criteria, but rather to glean insight into their beliefs about learning, their philosophy of teaching and the nature of science. These questions were intended to open up the discussion on learning and pedagogy and to help transition the interview to a focus on science in an approach which indicated that whatever the participant’s perspective was on the matter, it was valid and of interest to the research – that there were no ‘right’ or ‘wrong’ answers to the interview questions (as was noted throughout and stressed in conjunction with these questions in particular) and that capturing their unique perspective, knowledge and, in particular, their origins (i.e., experiences from which these ideas stemmed) was the task at hand. It was not anticipated that these two questions would alone warrant discussion as a major finding; however, the inability of half or better
of the preservice science teachers in this study to articulate an understanding of learning and science was deemed worthy of this attention.

Evidence.

Half of participants could not clearly define the construct of learning in their own words. The majority (68%) of participants could not articulate a definition of science with comprehensible parameters. (See Beliefs regarding pedagogy and Beliefs regarding content, Chapter 4 for further examples.)

Related experience.

While one participant who had just completed the Grad Dip program recalled an assignment in which he was asked to define learning, there was no indication that scaffolding or a follow-up discussion or activity assisted him in resolving the dilemma. He noted:

We actually had an assignment in one of our courses which was – normally you get an assignment and you expect this paragraph-long, or page-long or longer about you know ‘OK, this is what I want you to do, blah, blah, blah’ and it was just these three words: What is learning? …So that nature of it was quite different, and I think it caused everybody a lot of angst because they didn’t know what to say…and that’s where I’m still at! (Drew, interview, August 12, 2013)

This indicates a potential oversight of 'big picture' or foundational concepts (e.g., educational philosophy) in pedagogy courses in attempt to focus on general teaching strategies. While asking preservice teachers to define learning in their own terms is
certainly a valid constructivist approach, participant responses indicate inexperience in thinking about the process of learning.

The inability to explain the construct of science within comprehensible boundaries is likely symptomatic of the absence of an education course in the program related to science. While the undergraduate program includes seven science courses, these are not taught within the School of Education, but rather are geared toward development of knowledge of specific science subjects (e.g., anatomy and physiology, astronomy) and topics (e.g., evolution, cellular respiration) and do not likely address ‘science’ as a whole. Similarly, participants in the Grad Dip program have earned degrees in a specific scientific field (e.g., nursing, biochemistry) and it is likely that a focus on specific topics has precluded reflection on the broader concept of the nature of science.

Relevant literature.

Eliciting preservice teachers’ epistemological beliefs, or beliefs about the nature of knowledge and knowing, and having them reflect on their conception of knowledge and the process of learning can have substantial impacts on the effectiveness of teaching (Maclellan, 2015). Such beliefs not only influence pedagogical approaches to instruction, but serve as a fundamental conception of learning, critical thinking and knowing for teachers (Hennessey, Murphy, and Kulikowich 2013). Kukari (2004) suggests epistemological beliefs are the “philosophical basis of teaching and learning” (p. 107). Empirically, espoused goals for teaching have been linked to such beliefs (Kang, 2007; Levin & Wadmany, 2005). Findings indicate that teachers are more likely to embrace conceptual change pedagogy (Sinatra & Kardash, 2004), engage more frequently with
students and offer greater flexibility in student choices in learning (Schraw & Olafson, 2002) if they possess more sophisticated beliefs about knowledge and knowing.

The nature of science refers to “the values and underlying assumptions that are intrinsic to scientific knowledge, including the influences and limitations that result from science as a human endeavor” (Schwartz, Lederman, & Crawford, 2004, p. 611). Scientific inquiry refers to “characteristics of the scientific enterprise and processes through which scientific knowledge is acquired, including the conventions and ethics involved in the development, acceptance, and utility of scientific knowledge” (Schwartz et al., 2004, p. 611). An understanding of the nature of science is requisite for inquiry-based approaches to teaching science (Crawford, 2000). Strong content knowledge alone does not support an inquiry-based approach to teaching science, and an understanding of the nature of science is particularly important in yielding student-centered approaches to science teaching for teachers who possess a weaker knowledge of content (Roehrig & Luft, 2004). Teachers who have failed to reflect on and develop a conception of the nature of science are ill-equipped to scaffold their students’ understanding of the nature of science (Sariedenne & BouJaoude, 2014).

Experiences with inquiry have been noted to have intuitive appeal in supporting the development of nature of science conceptions, though empirical evidence does not support the notion that such experiences alone yield a well-developed understanding of the nature of science (Lederman, 1992; Ramsey & Howe, 1969). Schwartz et al. (2004) found that guided reflection is a necessary factor in the development of nature of science. They note that, while an understanding of the nature of science is not requisite to 'do'
science, it is necessary for teachers to understand the nature of science and inquiry, as well as to have related pedagogical knowledge, in order to effectively teach these constructs (Schwartz et al., 2004). Teacher preparation programs with an explicit focus on the nature of science paired with inquiry-based activities have been shown to be more effective at developing this concept among preservice teachers than those which attempt to do so implicitly through inquiry alone (Abd-El-Khalick & Lederman, 2000). Abd-El-Khalick (2005) found that preservice teachers enrolled in a philosophy of science course in addition to their science methods course developed a more robust understanding of the nature of science and were more likely to plan instruction focused on developing students' conceptions of nature of science than those who took a methods course alone.

Implications for teacher preparation.

Science education reforms promote a multifaceted focus on the nature of science, science knowledge and scientific processes (National Research Council, 2000; NGSS Lead States, 2013). It is therefore imperative that programs preparing science teachers provide opportunities for preservice teachers to explicitly and critically reflect on their beliefs and knowledge of these constructs. Participants in this study clearly demonstrate a lack of reflection on such beliefs, and it is likely they would benefit greatly from at least a subject-specific, if not discipline-specific, methods course. Preservice teachers in both traditional and alternative certification programs, such as the Grad Dip in the current study, should be encouraged and required to examine their own beliefs and preconceived conceptualizations of the nature of science, learning, teaching and knowledge. It is equally imperative that they are guided in their reflection on the ways in which these
beliefs align with their own teaching practice. Opportunities to experience student-centered pedagogies, from both a learner and teacher perspective, would provide preservice science teachers new experiences upon which to reflect on the nature of science as well as their own epistemological views. Drawing on the conceptual change learning in science, Bryan (2003) provides a useful approach to challenging beliefs through experience in which preservice teachers 1) identify their personal theories about practice; 2) experience scenarios that challenge personal theories of practice, requiring preservice teachers to consult colleagues and expert views; and 3) are provided opportunities to test solutions and reflect on outcomes.

**Finding 2: Motivation vs. Pedagogical Orientation**

A focus on motivation and interest as measurement of success, paired with a disconnect between expressed and enacted pedagogical orientation lead to teacher-centered instruction augmented with superficial tactics aimed at generating interest.

When participants spoke of their beliefs regarding the role of teachers, most focused on being a motivator or facilitator of learning, and the most cited belief about the relationship between teacher and students was a team scenario. Whether these beliefs stem from reflection on their own experience as a student or values espoused throughout the teacher preparation program, they cannot be translated into practice without the knowledge and experience to do so. With limited experience regarding student-centered teaching and learning, participants seem at a loss when translating these beliefs into practice. A ‘teach as I say, not as I teach’ approach to teacher education was noted throughout interviews. This model seems to leave preservice teachers ill-equipped for
student-centered learning. Even when participants find methods ineffective and espouse values contrary to those which they feel were underpinning their own formal education, without alternative experiences from which to draw, the preservice secondary science teachers in this study are limited in their TPACK development and default to teaching in the manner in which they have been taught. While they cite numerous experiences from a variety of contexts that have informed their pedagogical knowledge, such experiences are fairly similar and rigidly didactic in orientation. Given these circumstances, many participants, while hopeful they will be more engaging than teachers they have previously encountered, still articulate plans to teach in essentially the same manner.

**Evidence.**

*Focus on motivation and interest.*

In considering beliefs about technology, participants most frequently focused on its potential to motivate students and generate interest, as 30% of all cited affordances were in reference to motivation. In relaying beliefs about the role of the teacher, 53% of responses indicate the need for the teacher to act as a motivator. Regarding the students’ role, 55% of responses indicate that students should be a willing participant (i.e., give the teacher an opportunity to motivate and engage them). The need to get students attention and generate interest was iterated numerous times throughout interviews. In fact, preservice secondary science teachers in this study falsely equated a concern for student interest with pedagogical student-centeredness in teaching.
Teaching as inherently didactic.

Participants clearly articulated a need to teach science through direct instruction (see Table 8). Several relayed it as almost a necessary evil, as they noted their aversion to such didactic learning as students, but presented the approach as unavoidable. In fact, not only was a didactic approach viewed as necessary, but it was the only approach acknowledged as actual ‘teaching’ by some participants, who referenced more student-centered, technology facilitated activities as possibilities (see The repetition of educational history, Ch. 4). Use of technology for more student-centered learning is considered when time permits, after the ‘teaching’ has taken place (see Considerations, Chapter 4). This didactic perspective is also reflected in the participants’ descriptions of the student role, as the least frequent response was that students should be directors of their own learning.

The pairing of teacher-centered instruction with superficial motivation.

A disconnect exists between the student-centered orientation participants advocate and the didactic orientation participants adopt when discussing specific plans for instruction. The conflict between these expressed and enacted orientation values are often attributable to falsely equating teacher-as-facilitator and teacher-as-motivator roles (see Orientation, Chapter 4).

Numerous examples were given in chapter four findings of the disconnect between espoused and enacted beliefs regarding pedagogical orientation (see Orientation, Chapter 4) and participants’ inclination to teach the way they had been taught even when they did not always value teacher-centered approaches to instruction (see The repetition
of educational history, Chapter 4). The following quote further exemplifies a focus on motivation and interest with a lack of insight into learning as a process.

Researcher: What does learning mean to you?

Ellie: I think it’s more of a fun process so that you don’t have to sit there and write everything down and make sure it goes in and you’re ok for the exam…I think you have to be able to learn it fun so it goes in better.

Researcher: What happens in the process of learning – how do I know if I’ve learned something?

Ellie: (pause) I suppose at school you try and pass an exam or do an assignment properly but if there’s a question I’m trying to answer and I know it’s already in there (memory) and I don’t have to go look it up, then it’s there and I go ‘OK – learned that today.’ (interview, July 31, 2013)

After being asked about how she would help a secondary student conceptualize the idea of science, Ellie drew upon an experience she had as a seventh grade student in which her teacher took her class outside and asked them questions about the world around them for which they didn’t have answers. When asked why she felt this was an optimal approach to teaching science, she noted:

I think (students) need to be able to question things and be interested in those questions. I mean if you take them outside and say ‘Why’s this? Why’s that?’ and they say ‘I don’t care’ then they don’t really need to be in the science class because if they don’t care about how things work, then there’s really no point in trying to teach them. I think it’s good though because if we go ‘this is what we’re
learning about this semester’ then it’s planned and – ugh – I hate plans – and so when you get into it, then you start getting quite interested but you need to be able to get the students interested to start off. (interview, July 31, 2013)

This response indicates both a strong focus on student motivation and interest and a lack of breadth in sound science-related pedagogical strategies. Ellie draws from an experience she had as a student in which her teacher used open-ended questions to generate interest. While the effectiveness of this strategy was apparent to her as a student interested in the natural world, her reflection does not consider students who were less inspired by the approach nor does it glean insight from her teacher’s perspective, as the teacher’s knowledge of pedagogy or pedagogical content knowledge was not made explicit to the 7th grade students.

**Related experience.**

Experiences (or lack thereof) related to this finding include insufficient modeling of TPACK in the teacher preparation program and a lack of student-centered instructional experiences upon which to draw. Disconnects between espoused and enacted values regarding TPACK are modeled throughout the teacher preparation program (see Table 12).

Findings show insufficient modeling of TPACK exists in university-based experiences in this study. The majority of participants report TPACK modeling 50% or less of the time by university lecturers. Reports of TPACK modeling by mentor teachers in schools were mixed, with one third of participants each reporting this occurred 51-75%, 26-50% and 25% or less of the time. Relatedly, participants recounted, without
prompting, inconsistencies between approaches to the TPACK-informed teaching recommended to them and actual strategies employed in their teacher preparation program. In regard to orientation of teaching and learning, 75% of experiences recounted by participants were didactic in nature.

In looking across all contexts upon which the preservice secondary science teachers in this study reflect, the development of TPACK-related knowledge was attributed to participants’ experience as students in Pre-12 school 27% of the time. This includes 106 times participants drew upon their own time as a student, recounting ‘When I was in school…’ and ‘My science teacher used to…’ as experiences that informed their TPACK-related knowledge and, ultimately, their plans for practice. The Pre-12 school context was the most frequently cited context tied to the development of CK, PCK and TPACK and was nearly equal in influence to education courses in the development of PK. One could speculate a number of reasons for the significance of the Pre-12 school experience on preservice teachers – perhaps the length of time in which they were immersed in the experience vs. the relatively brief time they spend in their teacher preparation program; perhaps it was a transformative experience – one which lead them to their decision to become a science teacher. These all seem reasonable contributing factors. However, if a program is aimed at preparing individuals to teach science effectively (or, as in the case of a TPACK focus, to use technology to teach science effectively), one might posit that this context would be a far richer source of relevant, TPACK-related experiences - that an explicit focus on the development of this knowledge would outweigh whatever TPACK-related notions individuals gleaned from
their time on the other side of the lesson plan. It seems, however, that this is not the
experience preservice teachers are getting in their teacher preparation program. They
learn about science content; they learn about general teaching strategies; they may learn a
bit about technology, but the richest context for TPACK development – knowing how to
use technology to teach science – is still the Pre-12 classroom.

Relevant literature.

Talanquer, Tomanek, and Novodvorsky (2007) also found student motivation was
a main concern among preservice science teachers in their study on student teachers’
thinking through dilemma analysis. They noted that such concerns about teaching were
clearly grounded in participants’ personal beliefs. Mansfield and Volet (2010) found it
common for preservice teachers to cite the need for ‘fun’ and ‘interesting’ lessons to
stimulate student motivation. Their study found that preservice teachers with strong
preconceived notions about classroom motivation derived directly from their own
motivational preferences did not evolve over the course of the teacher preparatory
experience. Much like participants in this study, those who reported being disengaged in
their own school experience sought to infuse their lessons with somewhat superficial
‘add-ons’ (e.g., playing guitar for students at the end of the day and having physical
activity time after math work was completed) in order to increase student motivation
(Mansfield & Volet, 2010).

There is myriad research supporting the significance of teacher beliefs, as
evidenced in extensive reviews by Pajares (1992) and Raths and McAninch (2003), as
well as by Jones and Carter (2007), who focused their review specifically on science
teachers’ beliefs and attitudes. In attending to the debate regarding differentiating characteristics of beliefs and knowledge, Dole and Sinatra (1994) state “whether we call it knowledge or beliefs does not seem to us to be central to the research agenda”, as both seem synonymous, or at least equal of importance, in their impact on knowledge acquisition and change (p. 261). Lortie (1975) noted that this experience may hinder preservice teachers' ability to identify limitations of their knowledge, as they have well-developed notions of what it means to teach (and opinions on how to do it well). These beliefs are based only on their limited (student) perspective of teaching, however, as expert knowledge (i.e., the PCK or TPACK guiding the teacher's instructional decisions) has not been made explicit to them. Thus, Lortie notes that their teaching behaviors are intuitive and imitative as such behaviors remain largely unanalyzed (Lortie, 1975).

Borko and Putnam (2013) explain learning as "a constructive and iterative process in which a person interprets events on the basis of knowledge, beliefs and dispositions” and note that “although learning can be heavily influenced by instruction, how and what individuals learn is always shaped and filtered by their existing knowledge and beliefs" (p. 674). While beliefs have been found to influence practice (Cuban, 1986; Kagan, 1992; Niederhauser & Stoddart, 2001), successful experience with new approaches to practice can yield a shift in beliefs (Guskey, 1986). This aligns with the literature on self-efficacy (Bandura, 1997; Schunk, 2000).

With regard to beliefs about motivation and interest, Hubbard and Abell (2005) studied preservice science teachers in a methods course that promoted student-centered approaches to science education. They found that participants simultaneously enrolled in
an inquiry-based physics course were more likely to amend prior beliefs about inquiry learning to adopt this approach than those not enrolled in the inquiry-based physics course (and therefore not experiencing this approach from a learner perspective). Similar to participants in this study, the latter group was more likely to adhere to preconceived beliefs that teaching science should focus on creating a ‘fun’ (yet teacher-centered) experience for students (Hubbard & Abell, 2005).

Crawford (2007) found that despite a focus on student-centered, inquiry-based approaches to teaching science in their teacher preparation program, preservice teachers could not conceptualize concrete strategies for enacting these approaches in practice; beliefs about inquiry-based approaches to science education were identified as the most significant determinant for whether or not preservice teachers would adopt such approaches (Crawford, 2007). In a longitudinal study of a beginning biology teacher, Sickel and Friedrichsen (2015) found that the participant’s strong convictions about the importance of inquiry in science education were critical in overcoming contextual constraints for practice. Along with technological, pedagogical and content knowledge, teachers beliefs play a major role in determining use of technology for science instruction (Guzey & Roehrig, 2012).

While research on beginning science teachers' views of student-centered, inquiry-based instruction often shows that they are skeptical of its success in the classroom (Newman et al., 2004), participants in the current study often could not even conceptualize truly student-centered instruction in the science classroom. Smith (2005) found that among science teachers who experience didactic instruction as students in
school, those who do not have more engaging experiences with science outside of school are less likely to adopt reform-based instructional strategies than those who do. Of all learning experiences cited by participants in this study across informal and formal learning contexts, 75% were didactic in nature, and typically, the preservice science teachers in this study relayed plans for ‘transmission of knowledge’ type approaches to instruction. While this didactic approach to teaching is not uncommon among preservice science teachers (Brown, Friedrichsen, & Abell, 2013) even when in conflict with espoused beliefs (Bryan, 2003; Simmons et al., 1999), a unique finding in this study was that, rather than a simple bias toward direct instruction, several participants discuss teaching science as an inherently didactic process (see Table 8), indicating that any form of student-centered approach to learning did not necessarily fall under the category of ‘teaching’. A lack of consideration for the beliefs and prior knowledge of preservice science teachers will preclude the ability to impact teacher practice (Luft, 2001; Van Driel, Beijaard & Verlopp, 2001).

**Implications for teacher preparation.**

The current study highlights the impact of experience on beliefs and knowledge of preservice science teachers. As preservice teachers draw upon their experience to develop TPACK and TPACK-related knowledge and beliefs, modeling the types of reform-based teaching and learning advocated in teacher preparation programs is critical. While the disconnect between espoused and enacted values of student-centeredness and meaningful integration of ICTs for learning in the teacher preparation program did not escape participants in this study, the lack of modeled student-centered pedagogies left them ill-
equipped to translate such beliefs into practice. That is, while participants espoused values aligned with student-centered pedagogies (as encouraged by their experience in the teacher preparation program), in planning for practice, they had limited student-centered learning experiences upon which to draw and thus defaulted to teacher-centered approaches to instruction combined with more superficial approaches to increasing motivation and interest. Clearly, competence and confidence in sound, TPACK-informed practices must be fostered in order to change beliefs that stem from prior experience. Preservice teachers would benefit from successful modeling of student-centered pedagogies within their teacher preparation program. Preconceived notions about the didactic nature of science teaching and the value and purpose of ‘fun’ (and how to capture and maintain students’ attention) should be directly challenged by reflecting on such experiences from both a learner and teacher perspective.

**Finding 3: Integration Issues**

Difficulty in integrating knowledge bases leads to lower self-efficacy for TPACK, which has detrimental impacts on instruction.

**Evidence.**

*The difficulties of integrating knowledge bases.*

Participants reported the highest levels of self-efficacy for single knowledge components of TPACK, followed by dual components including pedagogy (PCK, TPK), followed by TPACK. Knowledge of science-specific technologies (TPK) yielded lowest reports of self-efficacy. Familiarity with content (7 courses in the undergrad and an entire Bachelor’s degree in a science for Grad Dip) along with the perceived concreteness of
CK yield high self-efficacy for this knowledge type among participants. Less experience with pedagogy and technology yielded slightly less self-efficacy for PK and TK, though still higher than any attempt to combine knowledge types. The preservice teachers in this study frequently referenced difficulties of and unpreparedness for pairing technology, pedagogy and content effectively. The university context was cited as the greatest impact on self-efficacy for TPACK, with 63% of experiences attributed to low levels of self-efficacy.

*Self-efficacy impacts instructional planning.*

Participants report that lower TPACK-related self-efficacy levels can lead to more didactic instruction, less authenticity and fewer attempts to integrate technology in teaching and learning experiences. While self-efficacy for content was fairly high, it is worthwhile to note that of all basic TPACK components (i.e., technology, pedagogy and content), content presents the fewest options for modification, followed by pedagogy and then technology. That is, required content is outlined by curriculum standards and is mandated to teachers. Pedagogy, while necessary, may be adapted and is often scaled back from more authentic, student-centered approaches to more didactic transmission of knowledge as self-efficacy declines. Last, technology is optional, often shifting from student-centered integration to teacher-centered use to complete omission with decreasing self-efficacy.
Related experience.

Underdeveloped technology-related forms of knowledge.

All technology-related forms of knowledge (TK, TCK, TPK and TPACK) were cited as lacking (i.e., non-existent) in the secondary teacher preparation program more frequently than as either positive or negative experiences. This demonstrates a lack of focus on technology in general within the university context, not only as technological knowledge, but in terms of what technologies are used in science, which technologies lend themselves well to various pedagogical approaches to teaching and learning and how to appropriately align technology with science teaching and learning goals.

The same lack of technology-related knowledge uncovered within the university context persists when considering all contexts referenced throughout participant interviews. While references to positive and negative TK-related experiences slightly outnumber references to the lack of such experiences, 40% of all references to TK are in regard to lacking experience. For TPK, TCK and TPACK, references to deficits outnumber references to actual experience.

Pedagogical-related forms of knowledge.

While participants draw upon experiences related to the development of their pedagogical knowledge more frequently than any other TPACK-related experiences across university contexts, there is a striking absence of university experiences upon which they can draw for pedagogical content knowledge, as indicated by the 27 references to a lack of PCK-related experience in relation to 11 positive and 7 negative
experiences referenced. This is likely attributable to the lack of a secondary science methods course.

The most frequently accessed experiences from the university context upon which participants draw are those tied to pedagogical knowledge. The greatest reported source of PK is education courses, followed by prac experience, followed by references to the program in general. No references, however, were linked to science courses, the greatest source of content knowledge reported in the university context. Likewise, no instances of content knowledge were referenced in education courses. The greatest source of the combination of these single knowledge bases, PCK, was prac experience.

*Content-related forms of knowledge.*

Clearly participants felt most confident in their knowledge of content, as self-efficacy levels for CK are the highest reported for all TPACK-related knowledge forms. This is likely due to the fact that participants in the undergraduate program take seven science courses in the university context and Grad Dip participants have an undergraduate degree in science. In regard to integrated content-related forms of TPACK, however, participants are less self-assured, reporting the lowest levels of TCK and serious difficulties in determining optimal pedagogical approaches to science topics (PCK) as well as how to use technology to teach science (TPACK).

*Relevant literature.*

Bandura (1997) suggests that teachers’ pedagogical decisions are largely based on self-efficacy. While participants in this study reported the highest levels of self-efficacy for content, this confidence can be somewhat problematic. Gess-Newsome (1999b) notes
that, even with a bachelors degree in a scientific field of study, preservice teachers’ knowledge of the content they will be teaching is “fragmented, compartmentalized, and poorly organized, making it difficult to access this knowledge efficiently when teaching” (p. 63). Habowski and Mouza (2014) point out that preservice teachers are unaware of the topics and in what sequence they are expected to teach until their methods class (absent entirely in this study) or practical experience, during which they become acquainted with standards, and the scope and sequence of curriculum. Despite higher levels of self-efficacy for CK, the fact that preservice teachers do not typically possess a robust or even entirely accurate knowledge of such topics results in their reliance on recall of facts and concepts from their own school experience as well as a default to more managerial approaches to instruction (Gess-Newsome, 1999b). In the absence of strong content knowledge, beliefs are the greatest determinant of practice, followed by an understanding of the nature of science (Roehrig & Luft, 2004). While Luft’s (2009) study focused on teacher induction programs, she noted that beginning teachers in science-specific programs were more likely to undergo a significant change in beliefs which translated to more student-centered approaches to practice than peers in non-subject-specific programs; this supports findings in the current study that suggest general pedagogy courses are not yielding student-centered beliefs or plans for practice among preservice secondary science teachers.

In regards to technology-related forms of knowledge, only half of the preservice teachers in this study enroll in a technology-related course, as the Grad Dip program does not include such a course. While such classes can increase familiarity with technologies,
often leading to increased productivity (Mims, Polly, Shepherd, & Inan, 2006; Polly & Shepherd, 2007; Wang, 2002), the ‘one-shot’ technology course does not typically yield changes in preservice teachers’ approach to teaching with technology in a way that significantly impacts student learning (Beyerbach, Walsh, & Vannatta, 2001; Wang, 2002). This type of technology course, as in the case of the undergraduate program in this study, typically lacks a connection with methods courses (Friedman & Kajder, 2006; Kay, 2006), focusing instead on basic technological skills. In the current study, not only does one program lack a technology course, but both lack subject-specific methods courses as well. Without these opportunities to explicitly focus on the effective integration of technology in teaching and learning, preservice teachers graduate with fundamental technical skills and familiarity with ICTs, but are likely to lack the ability to effectively plan for and utilize them effectively for teaching and learning (Andersson, 2006; Beyerbach et al., 2001; Wang, 2002).

While TPACK is most often discussed and researched from an integrative perspective (Doering, Scharber, et al., 2009; Hughes, 2008; Guzey & Roehrig, 2009; Koehler et al., 2007), in which development of any TPACK-related knowledge base inherently yields an increase in TPACK, the current study does not support this finding. Rather, preservice teachers who developed individual TPACK-related forms of knowledge cited multiple difficulties in synthesizing these knowledge bases into TPACK. This supports a more transformative perspective of TPACK (Angeli & Valanides, 2009). The notion that the integration of knowledge bases will occur naturally, effortlessly or even through greater experience with teaching is unfounded. Friedrichsen et al. (2009)
found no difference in pedagogical orientation nor PCK between participants with and without prior teaching experience when they entered an alternative certification program for secondary science teachers – both groups held didactic beliefs about teaching science, drew on general (i.e., not science-specific) pedagogical strategies, and lacked well-developed PCK.

TPACK-related knowledge is not enough on its own, as teachers must believe in the potential of technology to positively impact student learning in order to enact TPACK in planning technology-facilitated instruction (Ertmer, 2005). Bahr, Shaha, Farnsworth, Lewis and Benson (2004) noted that preservice teachers held more supportive views of technology-facilitated approaches to teaching and learning if they had observed or experienced such pedagogies throughout methods classes or practical experience. Wentworth, Waddoups and Earle (2004) found such experiences yielded greater technological knowledge. Preservice teachers who experience technology-facilitated teaching and learning in their teacher preparation programs self-identify at more advanced stages of technology adoption (Strudler, Archambault, Bendixen, Anderson, & Weiss, 2003) and are more likely to integrate technology in their teaching during practical experience (Krueger, Boboc, Smaldino, Cornish, & Callahan, 2004; Wentworth et al., 2004). Guzey and Roehrig (2009) found that, in order to maximize the effectiveness of technology integration and inquiry-based learning for science teachers, reflective practice is necessary.
Implications for teacher preparation.

*An integrated approach to TPACK development.*

This study reveals deficiencies in TPACK development in a model that silos the development of technological, pedagogical and content knowledge. Participants clearly articulate difficulties in attempting to combine these knowledge bases to effectively plan for instruction. An integrated approach to the development of TPACK is highly recommended in order to prepare teachers with viable strategies for effectively and meaningfully teaching science with technology.

*Exploiting the value of practical experience.*

The current study highlights the value of practical experience (i.e., time in the classroom) for preservice teachers. Prac was shown to be the most multi-faceted university context in terms of TPACK-related experiences. It is in this context that the preservice secondary science teachers in this study reported learning most about classroom management, a topic of great concern for beginning teachers. It is the only context in from which participants referenced every facet of TPACK, and the greatest source of PCK within the university context. In regard to self-efficacy, Bandura (1997) highlights the importance of experience in building confidence in one’s own capabilities, citing ‘enactive mastery experiences’ as the having the greatest positive impact. It is noted that, in order to yield the greatest increase self-efficacy, such experiences should be based in an authentic context and should require the individual to persevere through obstacles (Bandura, 1997). Practical experience is well-aligned to yield such opportunities for preservice teachers.
Practical experience strongly impacts preservice teachers' knowledge of representation and teaching strategies (De Jong et al., 2005; Grossman, 1990; Jang & Chen, 2010), allows them to make connections between knowledge bases (Lederman, Gess-Newsome, & Latz, 1994), and supports TPACK development (Jang & Chen, 2010). Research supports the effectiveness and importance of developing meaningful connections between practical experience and methods courses to afford preservice teachers the opportunity to enact and reflect on ideas and beliefs related to the nature of science (content-related) and inquiry-based practice (pedagogy-related) (Lotter, Singer, & Godley, 2009). It seems worthwhile to investigate the impact of increased time in the field or to develop and pursue opportunities to better integrate university coursework with practical experience in order to employ targeted and reflective development of TPACK.

**Recommendations for Future Research**

**The need to investigate experience as sources of TPACK development.**

The relationship between teachers' prior experiences and TPACK has not been sufficiently examined. This study found that prior K-12 experiences were a significant context informing the development of TPACK in pre-service secondary science teachers in this context. It is recommended that future studies continue to consider the greater context of experience (i.e., beyond the teacher preparation program) in examining the development of TPACK in preservice teachers.

**A visual model for representing contextual knowledge origins.**

The current study introduces a novel approach to the visual representation of knowledge and beliefs derived from various contextual experiences. The representations
illuminate the magnitude of influence of each context with regard to the development of TPACK-related knowledge. Future studies can utilize this approach to representing the relationships between different types of experiences and specific TPACK knowledge bases.

**Investigating best practices for integrated TPACK development.**

While this study points to a need for a more integrated approach to the development of TPACK within the teacher preparation program, the optimal approach to this integration is in need of investigation. Further study is necessary to determine if it is more effective to scaffold integration through the development of individual and/or dual knowledge components first or whether starting from a fully integrated approach yields better results. Habowski and Mouza (2014) note the lack of research on TPACK development in science teacher preparation programs. There is a need to look at a diversity of teacher education programs and the extent to which different structures can more effectively scaffold preservice teachers' integration of TPACK-related knowledge. A useful next step would be to study interventions that elicit preservice teachers’ preconceived notions and beliefs about TPACK derived from years of prior experience in the classroom. Approaches to directly challenging these beliefs through new experiences, scaffolding reflection and affording opportunities to implement and reflect on developing knowledge should be evaluated.

**A practical focus in TPACK research.**

There is a need for further investigation of the impact of beliefs for TPACK-informed teaching (Niess, 2008; Polly, Mims, Shepherd, & Inan, 2010; Voogt et al.,
While studies have revealed the connection between preservice and practicing teachers’ beliefs to be tied to their experience as a student, there is little research to consider influences beyond formal learning contexts (Smith, 2005).

Participants in this study relayed a common goal to generate interest through ‘fun’ or attention-grabbing experiences, indicating their ability to do so is perceived as an important indicator of their success as a teacher. Additional research is needed to determine the way in which beginning teachers evaluate their own success in teaching impacts their approach to pairing content, pedagogy, and technology for instruction.

Rather than simply measuring or evaluating teacher knowledge (Archambault, 2011; Archambault & Barnett, 2010; Archambault & Crippen, 2009; Chai, Koh, & Tsai, 2010; Chai, Koh, Tsai, & Tan, 2011; Doering, Veletsianos, Scharber, & Miller, 2009; Koehler & Mishra, 2005b; Koh, Chai, & Tsai, 2010; Lee & Tsai, 2010), a more applied focus on how knowledge is transformed into practice through the filter of beliefs and values would likely yield more practical, actionable implications for teacher preparation and professional development (Koh, Chai, & Tay, 2014).

**Conclusion**

The interplay of beliefs and experience in the development of TPACK and the manner in which TPACK is drawn upon in planning for instruction has been examined in this study. Prior to the commencement of the study, it was anticipated that the chosen context would uncover advantages in preparing secondary preservice teachers to employ technologies to effectively facilitate the teaching and learning of science. The study uncovered far more deficiencies than successes in the development of integrated TPACK.
While findings indicate a deficit of modeled student-centered teaching and learning and TPACK-informed instructional experiences in the teacher preparation program in the research context, they also point to their importance, as preservice teachers clearly articulated the need for such experiences to scaffold their development of TPACK. Given the lack of TPACK-based experiences upon which to draw in their teacher preparation program, participants attempt to recycle lessons, re-using familiar approaches to teaching science recalled from their experience as Pre-12 students. Findings suggest, however, that even this context does not provide a great deal of well-integrated TPACK-related experiences, and whatever the preservice teacher can recall of such experiences is devoid of insight from an expert knowledge perspective; that is, the knowledge upon which their teachers drew to plan and implement the instruction they experienced was not made explicit to them as a student at the time. Thus, drawing upon such experiences results in planning based on assumptions and is not likely to be reflective or well-informed. This further highlights the critical need to explicitly address TPACK knowledge bases and integrated forms of knowledge in teacher preparation programs.
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Appendix A: IRB Approval

A determination has been made that the following research study is exempt from IRB review because it involves:

Category 1. research conducted in established or commonly accepted educational settings, involving normal educational practices

Project Title: Technological Pedagogical Content Knowledge Development in Science Teacher Preparation

Primary Investigator: Jamie L. Smith

Co-Investigator(s):

Advisor: Teresa Franklin

(if applicable)

Department: Education

Jo Ellen Sherow, MPA
Office of Research Compliance

Date

5-29-13

The approval remains in effect provided the study is conducted exactly as described in your application for review. Any additions or modifications to the project must be approved (as an amendment) prior to implementation.
Appendix B: Survey of Preservice Teachers' Knowledge of Teaching and Technology

Demographic Data
Please provide your university e-mail address. Only the researcher will have this information – your identity will be kept completely confidential ____________

Gender a. Female b. Male

Age range a. 18-22 b. 23-26 c. 27-32 d. 32+

Year in College a. 1 b. 2 c. 3 d. 4 e. 5+

What grade level do you plan to teach? ____________

What subject(s) do you plan to teach? ____________

Approximately how many hours have you spent in field experience in a PK-20 classroom?

Technology is a broad concept that can mean a lot of different things. For the purpose of this questionnaire, technology is referring to digital technology/technologies. That is, the digital tools we use such as computers, laptops, iPods, handhelds, interactive whiteboards, software programs, etc. 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>TK (Technology Knowledge)</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>1. I know how to solve my own technical problems.</td>
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<td>2. I can learn technology easily.</td>
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<td>3. I keep up with important new technologies.</td>
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<td>4. I frequently play around with technology.</td>
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<td>5. I know about a lot of different technologies.</td>
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<td>6. I have the technical skills I need to use technology.</td>
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CK (Content Knowledge)


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<tr>
<td>7. I have sufficient knowledge about science.</td>
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<td>8. I can use a scientific way of thinking.</td>
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<td>9. I have various ways and strategies of developing my understanding of science.</td>
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<tr>
<td><strong>PK (Pedagogical Knowledge)</strong></td>
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<tr>
<td>10. I know how to assess student performance in a classroom.</td>
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<tr>
<td>11. I can adapt my teaching based upon what students currently understand or do not understand.</td>
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<td>12. I can adapt my teaching style to different learners.</td>
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<td>13. I can assess student learning in multiple ways.</td>
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<td>14. I can use a wide range of teaching approaches in a classroom setting.</td>
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<td>15. I am familiar with common student understandings and misconceptions.</td>
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<td>16. I know how to organize and maintain classroom management.</td>
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<tr>
<td><strong>PCK (Pedagogical Content Knowledge)</strong></td>
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<tr>
<td>17. I can select effective teaching approaches to guide student thinking and learning in science.</td>
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<tr>
<td><strong>TCK (Technological Content Knowledge)</strong></td>
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<td>18. I know about technologies that I can use for understanding and doing science.</td>
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<td><strong>TPK (Technological Pedagogical Knowledge)</strong></td>
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<td>19. I can choose technologies that enhance the teaching approaches for a lesson.</td>
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<tr>
<td>20. I can choose technologies that enhance students’ learning for a lesson.</td>
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<tr>
<td>21. My teacher education</td>
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<td>program has caused me to think more deeply about how technology could influence the teaching approaches I use in my classroom.</td>
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<td>22. I am thinking critically about how to use technology in my classroom.</td>
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<td>23. I can adapt the use of the technologies that I am learning about to different teaching activities.</td>
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<tr>
<td>24. I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn.</td>
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<tr>
<td>25. I can use strategies that combine content, technologies and teaching approaches that I learned about in my coursework in my classroom.</td>
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<td>26. I can provide leadership in helping others to coordinate the use of content, technologies and teaching approaches at my school and/or district.</td>
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<td>27. I can choose technologies that enhance the content for a lesson.</td>
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<tr>
<td><strong>TPACK (Technological Pedagogical Content Knowledge)</strong></td>
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<tr>
<td>28. I can teach lessons that appropriately combine science, technologies and teaching approaches.</td>
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<td><strong>Models of TPACK (Faculty, cooperating teachers)</strong></td>
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<tr>
<td>29. My science education professors appropriately model combining content, technologies and teaching approaches in their teaching.</td>
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<tr>
<td>30. My instructional technology</td>
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</table>
professors appropriately model combining content, technologies and teaching approaches in their teaching.

31. My educational foundation professors appropriately model combining content, technologies and teaching approaches in their teaching.

32. My professors outside of education appropriately model combining content, technologies and teaching approaches in their teaching.

33. My high school cooperating teachers appropriately model combining content, technologies and teaching approaches in their teaching.

<table>
<thead>
<tr>
<th>Models of TPACK</th>
<th>25% or less</th>
<th>26% - 50%</th>
<th>51% - 75%</th>
<th>76% - 100%</th>
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<tbody>
<tr>
<td>34. In general, approximately what percentage of your teacher education professors have provided an effective model of combining content, technologies and teaching approaches in their teaching?</td>
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<tr>
<td>35. In general, approximately what percentage of your professors outside of teacher education have provided an effective model of combining content, technologies and teaching approaches in their teaching?</td>
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<tr>
<td>36. In general, approximately what percentage of your cooperating teachers in high school have provided an effective model of combining content, technologies and teaching approaches in their teaching?</td>
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</table>
37. Describe a specific episode where a USQ professor or tutor effectively demonstrated or modeled combining content, technologies and teaching approaches in a classroom lesson. Please include in your description what content was being taught, what technology was used, and what teaching approach(es) was implemented.

38. Describe a specific episode where one of your cooperating teachers in high school effectively demonstrated or modeled combining content, technologies and teaching approaches in a classroom lesson. Please include in your description what content was being taught, what technology was used, and what teaching approach(es) was implemented. If you have not observed a teacher modeling this, please indicate that you have not.

39. Describe a specific episode where you effectively demonstrated or modeled combining content, technologies and teaching approaches in a classroom lesson. Please include in your description what content was being taught, what technology was used, and what teaching approach(es) was implemented. If you have not had the opportunity to teach a lesson, please indicate that you have not.
Appendix C: Permission to Use Survey of Preservice Teachers' Knowledge of Teaching and Technology

The following is the first page of the article, retrieved September 24, 2005 from http://mkoehler.educ.msu.edu/unprotected_readings/TPACK_Survey/tpack_survey_v1po_int1.doc

Survey of Preservice Teachers' Knowledge of Teaching and Technology

Denise A. Schmidt, Evrim Baran, and Ann D. Thompson
Center for Technology in Learning and Teaching
Iowa State University

Matthew J. Koehler, Punya Mishra, and Tae Shin
Michigan State University

Usage Terms: Researchers are free to use the TPACK survey, provided they contact Dr. Denise Schmidt (denschmidt@iastate.edu) with a description of their intended usage (research questions, population, etc.), and the site locations for their research. The goal is to maintain a database of how the survey is being used, and keep track of any translations of the survey that exist.

Version 1.1: (updated September 1, 2009). This survey was revised to reflect research results obtained from its administration during the 2006-2007 and 2009-2010 academic years. This document provides the latest version of the survey and reports the reliability scores for each TPACK domain. (This document will be updated as the survey is further developed).

The following papers and presentations highlight the development process of this survey:


How do I use the survey? The questions you want are most likely questions 1-46 starting under the header "TK (Technology Knowledge)". In the papers cited above, these categories were removed so that participants were not oriented to the constructs when answering the survey questions. The items were presented in order from 1 through 46, however. The other items are more particular to individual study and teacher education context to better understand results found on questions 1-46. You are free to use them, or modify them. However, they are not the core items used to measure the components of TPACK.

How do score the survey. Each item response is scored with a value of 1 assigned to strongly disagree, all the way to 6 for strongly agree. For each construct the participant’s responses are averaged. For example, the 6 questions under TK (Technology Knowledge) are averaged to produce one TK (Technology Knowledge) Score.
Appendix D: Semi-Structured Interview Protocol

Researcher role: The role of the researcher is to maintain empathic neutrality.

Purpose: The purpose of the interview is to gain an understanding of the nature of, self efficacy for, and beliefs about TPACK and what experiences have shaped these variables.

The interview begins with broader constructs and progress to more detailed topics, addressing learning and formal education, science, technology and the integration and application of technological, pedagogical and content knowledge.

Questions:
What does learning mean to you?

What is the teacher’s role in education?

What is the student’s role?

How do you see these roles interact?

Tell me about a really great learning experience you’ve had and what made it effective.

Can you think of a really terrible learning experience that made you think “I never ever want to teach this way”?

How do you think prior experiences have influenced the way you’re going to teach?

How do you think your experience in the teacher preparation program has influenced the way you’re going to teach?

Are there any other factors you feel might influence you as a future teacher?

What is science?

How would you help a secondary student conceptualize the idea of science?

What are key topics you’ll be responsible for teaching when you’re a teacher?

How confident are you in your content knowledge?

Do you see that there is a difference in terms of pedagogy between things you are very confident in teaching and content you need to reteach yourself before teaching?

Walk me through your lesson plan…
Do you start with technology, pedagogy, content or some combination when building a lesson? In what order do you consider these components in your planning?

Have you taken the ICT course?

Describe your use of technology on a daily basis.

What are some ways that you’ve used to learn new technology in the past?

Do you have a chance to play with/use technology in other courses – if you do a teaching demonstration, for example?

Can you talk through the process of planning a science lesson and how you would decide whether to use technology. If you decide to technology, how would you decide what technology to use?

Do you see technology being used effectively to teach in the teacher preparation program?

What would you say are your confidence levels in regard to technological, pedagogical and content knowledge?

Do you see these components being integrated or are they addressed separately in the teacher preparation program?

Do you feel it would be helpful for pedagogy, science content and technology to be integrated in your teacher prep experience or do you think it’s more effective to address them separately?

With all of these ideas you have about teaching with technology, do you feel like these come from you encountering the technology and thinking of implications for teaching yourself or have you seen many of these explicitly taught or modeled?

Are there any tech skills that you will have to teach as part of your science classroom or do you see that as more of an ICT class focus?
Appendix E: Permission to Use TPACK Diagram

The following screenshot was captured September 24, 2015 from tprack.org.