ACKNOWLEDGMENTS

I thank my ever-patient and loving family and friends. I also thank my chair, Kent Crippen for his persistent support every step of the way, and committee members, Susan Butler, Tim Jacobbe, Pam Soltis, and Sevan Terzian, for their valuable feedback. This dissertation would have never been possible without all of your help and encouragement. Lastly, I greatly appreciate the CPET staff and program participants for indulging me on this journey.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>3</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>8</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>9</td>
</tr>
<tr>
<td>LIST OF TERMS</td>
<td>10</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>11</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>1 INTRODUCTION</td>
<td>13</td>
</tr>
<tr>
<td>Statement of the Problem</td>
<td>13</td>
</tr>
<tr>
<td>Purpose</td>
<td>15</td>
</tr>
<tr>
<td>Methodology</td>
<td>16</td>
</tr>
<tr>
<td>Research Questions</td>
<td>19</td>
</tr>
<tr>
<td>2 CONCEPTUAL FRAMEWORK AND REVIEW OF THE LITERATURE</td>
<td>20</td>
</tr>
<tr>
<td>Overview</td>
<td>20</td>
</tr>
<tr>
<td>Teaching as Design Science</td>
<td>22</td>
</tr>
<tr>
<td>Teachers as Curriculum Adaptors</td>
<td>24</td>
</tr>
<tr>
<td>Teachers as Designers</td>
<td>26</td>
</tr>
<tr>
<td>Conceptual Framework</td>
<td>27</td>
</tr>
<tr>
<td>Professional Development for Science Teachers</td>
<td>29</td>
</tr>
<tr>
<td>Critical Features of Effective Professional Development</td>
<td>31</td>
</tr>
<tr>
<td>Content focus</td>
<td>31</td>
</tr>
<tr>
<td>Active learning</td>
<td>33</td>
</tr>
<tr>
<td>Coherence</td>
<td>34</td>
</tr>
<tr>
<td>Duration</td>
<td>35</td>
</tr>
<tr>
<td>Collective participation</td>
<td>36</td>
</tr>
<tr>
<td>Models of Professional Development</td>
<td>37</td>
</tr>
<tr>
<td>Teacher-Scientist Partnerships</td>
<td>40</td>
</tr>
<tr>
<td>Types of Teacher Knowledge</td>
<td>47</td>
</tr>
<tr>
<td>Pedagogical Design Capacity</td>
<td>49</td>
</tr>
<tr>
<td>Intersection of Pedagogical Reasoning, Competencies, and Design</td>
<td>51</td>
</tr>
<tr>
<td>Pedagogical Reasoning</td>
<td>51</td>
</tr>
<tr>
<td>Professional Competencies</td>
<td>51</td>
</tr>
<tr>
<td>Design Models</td>
<td>52</td>
</tr>
<tr>
<td>Activity Structures and Design Supports</td>
<td>53</td>
</tr>
<tr>
<td>Critical Features of Effective Professional Development</td>
<td>54</td>
</tr>
</tbody>
</table>
3 METHODOLOGY ........................................................................................................ 63

Purpose Statement and Research Questions .................................................................. 63
Introduction .................................................................................................................. 63
Conjecture Mapping ..................................................................................................... 66
Approach ..................................................................................................................... 68
Context ....................................................................................................................... 69
Research Location ...................................................................................................... 70
Participants ................................................................................................................ 71
Sampling Limitations ................................................................................................. 72
Data Collection .......................................................................................................... 73
Instruments .................................................................................................................. 75
  Biomedical knowledge assessment ........................................................................ 75
  PRIME PCK Rubric .................................................................................................. 79
  Curriculum design knowledge survey .................................................................... 82
  Science Lesson Plan Analysis Instrument (SLPAI) .............................................. 83
  Daily reflections ....................................................................................................... 85
  Storyline method .................................................................................................... 86
  Semi-structured interview ..................................................................................... 87
  Field notes ................................................................................................................ 88

Data Analysis ............................................................................................................. 89

Trustworthiness ......................................................................................................... 91
  Credibility or Construct Validity .............................................................................. 91
  Generalizability or External Validity ...................................................................... 92
  Dependability or Reliability ................................................................................... 93

Benefits and Limitations ............................................................................................ 93

Statement of Subjectivity ............................................................................................. 94

4 FINDINGS.................................................................................................................. 101

Findings for Research Question One: Influence of the TSP PD Program on
  Teacher Professional Knowledge .............................................................................. 101
  Subject Matter Knowledge ...................................................................................... 101
  Pedagogical Content Knowledge .......................................................................... 103
  Curriculum Design Knowledge .............................................................................. 105
  Evidence of Professional Knowledge in Reflective Journals .............................. 108
    Personal learning .................................................................................................. 109
    Pedagogical practices ......................................................................................... 111
    Instructional design decisions ............................................................................ 112
    Engagement ......................................................................................................... 114

Findings for Research Question Two: How Professional Knowledge Relates to
  Design Expertise ...................................................................................................... 116
Analysis of Design Expertise ............................................................... 116
Professional knowledge types within the SLPAI as related to design expertise .......................................................... 117
Professional knowledge types within the reflective journals as related to design expertise ............................................ 121
Findings for Research Question Three: Participant Perceptions of the TSP PD Program Activity Structures and Design Supports ................................................................. 123
Storyline Reflective Method ............................................................... 124
Laboratory experience ....................................................................... 125
Evening design sessions ..................................................................... 125
Interactions with former intern ............................................................. 126
Curriculum writing .............................................................................. 126
Individual curriculum design meetings with coordinators ...................... 126
Whole group interactions .................................................................... 127
Reflective journals ............................................................................ 128
Informal conversations with peers ........................................................ 128
Analysis of Interviews ....................................................................... 128
Subject matter learning ...................................................................... 129
Active learning .................................................................................. 131
Collective participation ...................................................................... 132
Duration ............................................................................................ 133
Coherence ........................................................................................ 135
Role of program ............................................................................... 137
Models and materials ........................................................................ 139
Explicit design model ....................................................................... 140
Conclusion ........................................................................................ 142

5 DISCUSSION ................................................................................... 158

Overview .......................................................................................... 158
Influence of the TSP PD Program on Teacher Professional Knowledge .............................................................. 161
Comparison to Pilot Study .................................................................. 162
Authentic Research Setting .................................................................. 163
Study Instruments ............................................................................... 165
How Professional Knowledge Relates to Design Expertise ...................... 168
Participant Perceptions ...................................................................... 170
Laboratory Experience ...................................................................... 171
Curricular Template .......................................................................... 172
Collective Participation ...................................................................... 173
Conceptual Framework Revisited ........................................................ 174
Implications for Science Education Research ...................................... 177
Recommendations for Stakeholders of Teacher-Scientist Partnership Programs .......................................................... 181
Limitations ........................................................................................ 183
Conclusion ........................................................................................ 186

APPENDIX
A  RESEARCH LABORATORY DESCRIPTIONS ................................................................. 189
B  SUMMER RESEARCH EXPERIENCE APPLICATION ........................................... 193
C  INFORMED CONSENT ......................................................................................... 195
D  CURRICULAR TEMPLATE .................................................................................... 198
E  BIOMEDICAL KNOWLEDGE ASSESSMENT ...................................................... 202
F  PRIME PCK RUBRIC .......................................................................................... 205
G  PRIME PCK PROMPT .......................................................................................... 207
H  CURRICULUM DESIGN KNOWLEDGE SURVEY ............................................. 209
I  SCIENCE LESSON PLAN ANALYSIS INSTRUMENT (SLPAI) ............................ 213
J  DAILY REFLECTION ............................................................................................ 218
K  STORYLINE METHOD .......................................................................................... 244
L  SEMI-STRUCTURED INTERVIEW PROTOCOL ................................................... 246
M  FIELD NOTES OBSERVATION CHECKLIST ..................................................... 247
N  CURRICULUM SUMMARIES AND SLPAI REVIEWS ...................................... 248
O  CODEBOOK ........................................................................................................ 257
P  LIST OF REFERENCES .......................................................................................... 266
Q  BIOGRAPHICAL SKETCH .................................................................................... 277
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-1</td>
<td>Comparison of design models.</td>
<td>62</td>
</tr>
<tr>
<td>3-1</td>
<td>Activity structures and design supports of the Summer Research Experience</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>teacher-scientist partnership professional development program.</td>
<td></td>
</tr>
<tr>
<td>3-2</td>
<td>Participant profile of 2016 Summer Research Experience TSP PD program.</td>
<td>99</td>
</tr>
<tr>
<td>3-3</td>
<td>Research questions, constructs, associated instruments, and data sources.</td>
<td>100</td>
</tr>
<tr>
<td>4-1</td>
<td>Biomedical Knowledge Assessment scores as measure of SMK.</td>
<td>144</td>
</tr>
<tr>
<td>4-2</td>
<td>PRIME PCK reflection scores on protein synthesis as a measure of PCK.</td>
<td>145</td>
</tr>
<tr>
<td>4-3</td>
<td>CDK survey scores as a measure of curriculum design knowledge.</td>
<td>146</td>
</tr>
<tr>
<td>4-4</td>
<td>Results of related samples Wilcoxon Signed Rank test for curriculum design</td>
<td>147</td>
</tr>
<tr>
<td></td>
<td>knowledge.</td>
<td></td>
</tr>
<tr>
<td>4-5</td>
<td>Individual item scores based on CDK survey responses.</td>
<td>149</td>
</tr>
<tr>
<td>4-6</td>
<td>Individual item normalized gain scores based on CDK survey responses.</td>
<td>150</td>
</tr>
<tr>
<td>4-7</td>
<td>Activities structures corresponding to reflective journal prompts.</td>
<td>151</td>
</tr>
<tr>
<td>4-8</td>
<td>Reflective journal Likert scale responses.</td>
<td>152</td>
</tr>
<tr>
<td>4-9</td>
<td>SLPAI scores as an indicator of design expertise.</td>
<td>154</td>
</tr>
<tr>
<td>4-10</td>
<td>SLPAI criteria, knowledge alignment, and category scores.</td>
<td>155</td>
</tr>
<tr>
<td>4-11</td>
<td>Storyline activity structures and design supports.</td>
<td>156</td>
</tr>
<tr>
<td>4-12</td>
<td>Sample comments for storyline activity structures and design supports.</td>
<td>157</td>
</tr>
</tbody>
</table>
**LIST OF FIGURES**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-1</td>
<td>Teachers’ design expertise overview in teacher design teams</td>
<td>57</td>
</tr>
<tr>
<td>2-2</td>
<td>Teachers’ design expertise is represented by the integration of subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge.</td>
<td>58</td>
</tr>
<tr>
<td>2-3</td>
<td>An implicit model of the purpose of teacher professional development</td>
<td>59</td>
</tr>
<tr>
<td>2-4</td>
<td>The interconnected model of professional growth</td>
<td>60</td>
</tr>
<tr>
<td>2-5</td>
<td>Conceptual framework for studying the effects of professional development on teachers and students.</td>
<td>61</td>
</tr>
<tr>
<td>3-1</td>
<td>High level, design, and theoretical conjectures</td>
<td>96</td>
</tr>
<tr>
<td>3-2</td>
<td>Embodiments, mediating processes, and outcomes</td>
<td>97</td>
</tr>
<tr>
<td>4-1</td>
<td>Participant mean level of agreement for each CDK element at pre, retrospective, and post administrations.</td>
<td>148</td>
</tr>
<tr>
<td>4-2</td>
<td>Reflective journal Likert scale response means</td>
<td>153</td>
</tr>
<tr>
<td>5-1</td>
<td>Conceptual framework of the professional knowledge types needed to develop design expertise in the context of this study’s TSP PD program</td>
<td>188</td>
</tr>
</tbody>
</table>
**LIST OF TERMS**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center for Precollegiate Education and Training (CPET)</td>
<td>University center tasked with assisting scientists, engineers, and clinicians to communicate their research to broader audiences, foster the interest of precollege students and teachers in STEM research, and provide opportunities for precollege teachers to increase and update their professional knowledge and skills</td>
</tr>
<tr>
<td>Conjecture mapping</td>
<td>A means of specifying theoretically salient features of a learning environment design and mapping out how they are predicted to work together to produce desired outcomes</td>
</tr>
<tr>
<td>Curriculum design knowledge (CDK)</td>
<td>The technical knowledge and skills required to enact the design of learning experiences which are consistent with local and national education contexts using a systematic design approach</td>
</tr>
<tr>
<td>Design-based research (DBR)</td>
<td>Research methodology in which interventions are conceptualized and then implemented iteratively in natural settings in order to test existing theory and to generate new theories and frameworks for conceptualizing learning, instruction, design processes, and educational reform</td>
</tr>
<tr>
<td>Design expertise (DE)</td>
<td>The required skills and knowledge needed to purposefully design quality curriculum materials and learning experiences for the science classroom</td>
</tr>
<tr>
<td>Professional development (PD)</td>
<td>Teacher learning through various activities designed to enhance the professional knowledge, skills, and attitudes of teachers with the goal of improving the learning outcomes of their students</td>
</tr>
<tr>
<td>Teacher as designer</td>
<td>A practicing educator who utilizes design principles and embodies professional teacher competencies as they purposefully design learning experiences best suited for their unique classroom context</td>
</tr>
<tr>
<td>Teacher-scientist partnership (TSP)</td>
<td>A collaboration between teachers and scientists with the common goal of improving K-12 science education, often through sharing knowledge and expertise from each respective field that results in the creation of new science learning experiences</td>
</tr>
</tbody>
</table>
DEVELOPING DESIGN EXPERTISE THROUGH A TEACHER-SCIENTIST PARTNERSHIP PROFESSIONAL DEVELOPMENT PROGRAM

By

Julie Renee Bokor

December 2016

Chair: Kent J. Crippen
Major: Curriculum and Instruction

There is little research on how and to what extent teachers engage in the process of design, particularly in the context of translating a teacher-scientist partnership professional development (TSP PD) program into learning experiences for the K-12 science classroom. This qualitative single case study of an existing TSP PD program aimed to understand the activity structures and design supports that foster science teachers’ ability to design learning experiences for their classroom context. The conceptual framework considered design expertise as the integration of a set of professional knowledge and skills, each contributing equally. Conjecture mapping provided an explicit description of how learning may occur in a particular environment and the interaction of the variables under investigation. Design-based research (DBR) was utilized as a form of inquiry based on empirical research and theoretical considerations of the designed setting and its influence on learning. Quantitative instruments were used to assess subject matter knowledge (SMK), pedagogical content knowledge (PCK), curriculum design knowledge (CDK), and design expertise. Participant perceptions were considered through additional data sources including daily reflective journals, semi-structured interviews, and a storyline reflective method.
There were no changes in SMK and PCK based on the objective measures. However, there was a gain in CDK. Additionally, the participants' daily reflective journals reveal they perceive differences in their personal learning, pedagogical practices, and instructional design decisions as a result of the TSP PD program. All participants demonstrated a successful level of design expertise, producing curricula for use in their classrooms. The participants indicated the activity structures and design supports were mainly affordances however there were some constraints to their design expertise. The findings suggest TSP PD programs situated in authentic research laboratories may not be an appropriate form of professional development to increase SMK or PCK unless explicit learning supports are included in the program design which additionally must be well aligned with the program goals and associated outcome measures. This study proposes a new conceptual framework for the integration of professional knowledge leading to design expertise in which CDK is a necessary knowledge type that provides the foundation for design.
CHAPTER 1
INTRODUCTION

Statement of the Problem

Teachers are tasked daily with designing educational learning experiences for their students and are additionally expected to translate professional development experiences into classroom practice. However, there is little research on how and to what extent teachers engage in the process of design as an iterative cycle of analysis, design, development, implementation, and evaluation (ADDIE, Gustafson & Branch, 2002; Huizinga, 2014), particularly in the context of translating a teacher-scientist partnership professional development (TSP PD) program into learning experiences for the K-12 science classroom. As teachers engage in the process of design and draw on their professional knowledge, they are able to develop design expertise defined as “the required knowledge and skills to design quality curriculum materials” (Huizinga, 2014, p. 7). There is scholarship which acknowledges that teacher participants adapt professional development experiences into classroom practice (e.g., Dresner & Worley, 2006), but to date, there is no study that investigates the design expertise a teacher needs to translate a university-based TSP PD program that immerses the teacher in an authentic research laboratory into a productive learning experience via the creation of a curricular module for secondary science students.

A teacher-scientist partnership is broadly defined as a collaboration between teachers and scientists with the common goal of improving K-12 science education, often through sharing knowledge and expertise from each respective field that results in the creation of new science learning experiences (Tanner, Chatman, & Allen, 2003). Although these two partners may have similar interests in scientific discovery and
pursuit of scientific knowledge, the differences in the cultural climate of each field and societal perspectives regarding who holds authority can inhibit a true teacher-scientist partnership (Tanner et al., 2013). The traditional TSP model generally focuses on science content delivery from the scientist with the expectation that teachers will be able to translate their experience into materials for their students (Dresner & Worley, 2006). There is a rich history of scientists’ involvement in the classroom and TSP PD programs from single day classroom visits to extended summer-long research apprenticeships, however, there is limited scholarship regarding the goals, structure, and outcomes of the programs (Klein-Gardner, Johnston, & Benson, 2012; Rudolph, 2002). Often TSPs are initiated by scientists and funded via a science discipline grant (e.g., National Science Foundation Research Experience for Teachers, NSF RET; National Institutes of Health Science Education Partnership Award, NIH SEPA) for the purpose of outreach and broader impacts rather than focusing on empirical science education research. Recent works have concentrated on National Science Foundation Research Experience for Teachers (NSF RET) programs and the translation of the RET experience into classrooms mostly in the form of reviews, assembled largely from searching program websites and isolated research and evaluation reports but with only a handful considering the translation of the research apprenticeship experience into classroom practice through materials development (Herrington, Luxford, & Yezierski, 2012; Klein-Gardner et al., 2012; Miranda & Damico, 2013.) With continued calls for effective (Desimone, 2009) and transformative (Parke & Coble, 1997; Thompson & Zeuli, 1999) professional development for science teachers which embodies a core set of features to increase teacher professional knowledge and instruction that leads to enhanced student
achievement (Desimone, 2011; Desimone, Porter, Garet, Yoon, & Birman, 2002; Garet, Porter, Desimone, Birman, & Yoon, 2001; Penuel, Fishman, Yamaguchi, & Gallagher, 2007), combined with funding incentives for scientists to engage in K-12 education and with broader audiences, there is a need to better understand how to develop TSP PD programs that build the knowledge and skills needed to support teachers as designers of new learning experiences for their classroom and effectively translate current science findings to their students. Teachers often self-report positive perspectives related to their TSP PD, however, in content-driven TSP PD programs, other forms of teacher knowledge, such as pedagogical knowledge and pedagogical content knowledge may be minimized or de-emphasized (Schuster & Carlsen, 2009), hindering the translation of the TSP PD experience into the classroom context in an observable fashion. Without purposeful investigation of the activity structures and design supports and their alignment with professional knowledge bases, empirical evidence of how and to what extent the TSP PD experience is translated into professional knowledge and improved teaching and learning consistent with the calls from the Framework for K12 Science Education and Next Generation Science Standards is lost.

**Purpose**

The purpose of this study is to explore how teachers’ engagement with the activity structures and design supports of a teacher-scientist partnership professional development program influences their professional knowledge and develops their design expertise for translating the TSP PD into a learning experience specific to the education goals for their classroom context. Specifically, this study aims to understand the activity structures and design supports of a TSP PD that foster science teachers’ ability to design learning experiences for their classroom context and how their design
expertise relates to other forms of teacher knowledge such as subject matter knowledge and pedagogical content knowledge. Activity structures and design supports are components of the TSP PD program that provide scaffolding to help develop teacher professional knowledge through reactive and proactive structures according to the goals of the program (Huizinga, Handelzalts, Nieveen, & Voogt, 2014; 2015). Example activity structures and design supports include features such as the use of curriculum design templates and models, educative materials, and explicit instruction in the use of a design model as well as inclusion of the core features of PD such as active learning strategies, support for subject matter learning, and collective participation (Huizinga et al., 2014; 2015; Penuel, Gallagher, & Moorthy, 2011).

**Methodology**

This study seeks to understand the complex interactions of the designed intervention (TSP PD program) and outcomes (development of design expertise) in an authentic learning context. As such, design-based research (DBR) as a form of inquiry is utilized in this study and is based on empirical research and theoretical considerations of the designed setting and its influence on learning (Barab & Squire, 2004; Design-Based Research Collective, 2003; Hoadley, 2004; Sandoval, 2004).

The Center for Precollegiate Education and Training (CPET) is an outreach center situated in the Provost’s office, and tasked with assisting the university community with efforts to share research findings with broader audiences. CPET focuses on precollege students and teachers, coordinating multiple programs each year with some ongoing for more than 50 years. In the last two decades, additional professional development programs have been funded by grants to CPET from the National Science Foundation, the Woodrow Wilson Foundation, the Howard Hughes
Medical Institute, and specific for this current study, the National Institutes of Health Science Education Partnership Award (NIH SEPA). The current NIH SEPA program aims to increase teacher understanding of biomedical science research and translational medicine and equip them with the knowledge, skills, and resources to infuse biomedical science into their classroom curriculum.

The current TSP PD program combines aspects of a summer institute and an extended research apprenticeship program (e.g., RET) based on previous research and evaluation of CPET’s TSP PD programs. For example, a previous summer-long research experience revealed the length of time was prohibitive for many teachers and the placement in one research laboratory was restricting for some, but the accompanying research lectures were appreciated (Barnes, Hodge, Parker, & Koroly, 2006). In shorter two-week summer institutes, teachers once again valued the content delivered by scientists and the experience learning new laboratory techniques, but wanted to be immersed in authentic research laboratories for extended times and engage in singular topics more deeply (Borgerding, Sadler, & Koroly, 2013; Bokor & Crippen, 2016). In both situations, teachers expressed numerous affordances (e.g., active learning, classroom-ready materials, equipment lockers) and constraints (e.g., pacing guides, classroom contexts, not enough reflection during the program) to translating the TSP PD program into classroom lessons (Brown, Bokor, Crippen, & Koroly, 2014). The current TSP PD program builds on the 20+ year history of TSP PD programs offered by the same university outreach center as the current iteration in DBR of CPET’s TSP PD model, and it is this previous work, as well as the limited empirical
findings, that call for a focused inquiry of how to support teachers as designers through effective TSP PD programs.

To frame the inquiry, conjecture mapping provides an explicit description of how learning may occur in a particular environment and the interaction of the variables under investigation (Sandoval, 2014). The overarching construct guiding the investigation is the high-level conjecture that provides rigor and theoretical grounding. The high-level conjecture of this study posits that developing science teachers’ design expertise through a TSP PD program requires providing varied activity structures that support first person authentic science learning (e.g. conversations with researchers, immersion in active research laboratories) and purposeful design supports in order to enhance teachers’ professional knowledge (subject matter knowledge, pedagogical content knowledge, curriculum design knowledge) and skills for translating the experience into designed lessons specific to the education goals for their classroom context.

The conceptual framework for this study draws from the work of Huizinga (2014) to consider design expertise as a complex set of knowledge and skills, specifically subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge. Conjecture mapping is a technique for conceptualizing design research which Sandoval (2014) describes as “a means of specifying theoretically salient features of a learning environment design and mapping out how they are predicted to work together to produce desired outcomes” (p. 19). Conjecture mapping affords a lens to view the learning environment of the TSP PD program in this study and provides a scaffold to develop a high-level conjecture (i.e., overarching construct guiding the design experiment); a design conjecture which conveys the connections between the
embodiments (i.e., participant engagement with activity structures and design supports) and the mediating processes (i.e., observable interactions and artifacts of SMK, PCK, and PCK); and a theoretical conjecture to link the mediating processes with the outcomes (i.e., design expertise exhibited through the creation of a designed curricular product). Articulating these elements allows us to consider the many factors influencing a learning environment in a systematic fashion. The research questions for this study arose from a design-based research paradigm and were explored through a single case method within an existing TSP PD program.

**Research Questions**

The purpose of this study was to explore how teachers’ engagement with the activity structures and design supports of a teacher-scientist partnership professional development program influences their professional knowledge and develops their design expertise for translating the TSP PD into a learning experience specific to the education goals for their classroom context. The research questions for this study were:

- **RQ1:** How do the activity structures and design supports of the TSP PD influence subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge?
- **RQ2:** How do changes in subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge relate to the development of design expertise?
- **RQ3:** How do participants perceive the activity structures and design supports of a teacher-scientist partnership professional development program affording or constraining their design expertise?
CHAPTER 2
CONCEPTUAL FRAMEWORK AND REVIEW OF THE LITERATURE

This chapter begins byarticulating the conceptual framework for this study of teaching as a design science and the knowledge and skills needed to develop design expertise followed by a review of the literature regarding teacher professional development (PD) and the role of teacher-scientist partnerships (TSP) in supporting science teacher professional learning. It explores teachers’ professional knowledge, including a discussion of professional teacher competency and instructional design models, and concludes by articulating activity supports and design features of PD that support teachers as designers of rich learning environments for their classroom context.

Overview

The conceptual framework for this study draws from the work of Huizinga (2014) to consider design expertise as a complex set of knowledge and skills, specifically subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge. Subject matter knowledge and pedagogical content knowledge are reviewed briefly as these knowledge types are well articulated in the literature, however curriculum design knowledge is a construct original to this study and the literature informing its development is considered. The construct at the heart of this study is design expertise—an amalgam of subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge—which is elaborated through the limited scholarship of others considering teachers as designers, building primarily from Huizinga’s work (2014) with teacher design teams and underlying instructional design literature. The conceptual framework of this study falls within a larger idea of teachers as designers and the recent literature describing teaching as a design science. This
work recognizes the purposeful steps teachers undertake to design instruction episodes using the instructional design cycle of analyze, design, develop, implement, and evaluate (ADDIE, Gustafson & Branch, 2002). However, previous work has shown that teachers seldom engage in all stages of the design process (Huizinga, 2014), suggesting design support is needed to scaffold teacher learning for design.

Professional development might be a means to foster the development of teachers as designers.

Teacher professional development is a broad term that encompasses a range of activities and expectations and similarly the accompanying literature is quite extensive. Little (1987) described professional development as “any activity that is intended partly or primarily to prepare paid staff members for improved performance in present or future roles in the school districts” (p. 491). Additionally, professional development incorporates many forms of teacher learning through various activities designed to enhance the professional knowledge, skills, and attitudes of teachers with the goal of improving the learning outcomes of their students (Guskey, 2003). Some researchers include accidental and informal events in their description of PD, considering PD to be an ongoing and life-long construct (Borko, 2004) while others restrict the definition to purposefully designed learning episodes to bound their study (van Driel, Meirink, van Veen, & Zwart, 2012). The literature review will focus on the latter interpretation of PD, concentrating on the structured activities designed by a PD facilitator with the intention of enhancing professional knowledge and skills of teachers with the goal of improving student learning outcomes. In this vein, there is a general consensus as to the best practices of effective professional development, or rather, the supports that should be in
place to facilitate teacher learning. These best practices or PD features are elaborated in this chapter (e.g., Desimone, 2009; Garet, Porter, Desimone, Birman, & Yoon, 2001). Additionally, an exploration of TSPs relevant to this study is considered with particular attention to the goals of different program types. A review of the literature suggests that many TSPs are content-focused and follow the model of experts delivering knowledge to learners with limited understanding of events that occur beyond the campus setting. This study attempts to understand how teachers translate their TSP PD experience into learning episodes for their classroom context, and how teachers engage in the design process to do so resulting in the development of design expertise and consequently, teachers fulfilling the role of designer.

**Teaching as Design Science**

Teaching is often considered an art (Laurillard, 2012) or craft (Brown, 2002) because it requires imagination and creativity. However, these characteristics do not adequately describe the purposeful, goal-oriented process that teachers may undertake to construct meaningful learning experiences for their students and guide them to understanding new science concepts and processes. Rather, considering teaching from the perspective of design science and therefore, teachers as designers, more accurately describes the complex nature of education particularly in the increasing knowledge-based society of the 21st century. Design science is practical and immediately useable: it articulates heuristics and practices, yet contributes to formulating explanations and theories (Laurillard, 2012). Teachers are similar to other design professionals such as architects, engineers, and programmers as they must devise creative and evidence-based ways of improving their work while they design new solutions in an ever changing cultural and technological environment (Laurillard, 2012).
Teachers are designers and as such engage in the process of design, defined broadly as the “process of mapping and/or actually developing specific resources for teaching or learning” (Kali, McKenney, & Sagy, 2015, p. 174).

As viewed in this study, teaching as a design science and specifically teachers as designers places more design control with the teacher as compared to previous work by Brown and Edelson (2003) – the only work within science education to address teaching as a design science. In their study, they investigated the ways teachers designed a learning experience using educative curricular materials created by a team of science education researchers, curriculum writers, and scientists. Educative materials are developed to promote both teacher and student learning (Davis & Krajcik, 2005). In Brown’s research (2002), the curricular foundation was already in place and guided the middle school teachers through a developed lesson sequence on global warming. Educative materials provide scaffolding for a teacher as he or she builds an instructional episode from materials produced by others. In this situation, teachers indeed design a new learning experience for their students, as all design is simply re-design or modification of an activity previously completed, but they do so starting with fully-developed materials that are being adapted to some degree. The degree of adaptation is specific to the personal and professional resources that the teacher draws from, but these resources are combined with the materials already in place, with the goals already described. In this study, teachers are designing original educative materials, starting with the authentic experiences of a university research setting and proceeding through the step-wise fashion of the design cycle to create a learning episode captured
as an instructional unit that strives to achieve the teacher’s instructional goals based on their analysis of student needs and instructional objectives.

**Teachers as Curriculum Adaptors**

Teachers select and adapt materials to suit the needs of their students (Ball & Cohen, 1996). Brown and Edelson (2003) described teachers as designers as they adapted educative materials for classroom use, however, their description is consistent with what other researchers have described as curriculum adaptation, not teachers as designers as it is operationalized in this study. Barab, Luehmann, and colleagues (2003) investigated how teachers incorporate project-based, technology-rich curricula into their classroom, specifically with the researchers’ intent of understanding how to successfully design materials that scaffold teacher learning and provide structure while allowing flexibility for local adaptation by the teacher (Barab & Luehmann, 2003; Squire, MaKinster, Barnett, Luehmann, & Barab, 2003). They stress the idea that teachers will necessarily adapt materials to better accommodate their local context due to the complexity of their “classroom culture” which includes all of the tools and resources of the physical environment as well as the dynamics introduced by the students, administrators, parents, and the teachers themselves. Indeed, Squire and colleagues (2003) state those designing new curricular innovations “need to acknowledge that their designs are not self-sufficient entities; instead, during implementation, they become assimilated as part of the cultural systems in which they are being realized” (p. 468). In a study of past participants of the Teachers in the Woods Research Experience for Teachers (RET) program, Dresner and Worley (2006) provide an example of a teacher’s perspective on the necessity of adaptation. During a post-program interview, a high school teacher stated “Curriculum guides are not written for high school teachers
who want to turn their kids on to science. The way the program proceeded, with other teachers giving their workable solutions, has really allowed me to find my own format for students to use in the field” (p. 6). As this teacher shares, modifications were made to better suit the needs of the students as determined based on the teacher's professional knowledge and understanding of the students.

The traditional TSP model generally focuses on science content delivery from the scientist to deepen the teachers' content knowledge (Ha, Baldwin, & Nehm, 2015) with the expectation that teachers will be able to translate their personal experience into learning experiences for their students (Dresner & Worley, 2006). Herrington and colleagues (2012) report that many RET programs require the development of lesson or unit plans and have teacher curricular products posted on the associated RET program website, suggesting that teacher participants are expected to produce a product, perhaps as evidence of outcomes of the funded program. Implicit in this finding is that teachers are expected to translate their PD experience into the classroom, or adapt their professional development experience to their classroom context. However, adaptation or general lesson planning does not require the process of design and the resulting TSP PD products vary widely, even when scaffolding such as lesson templates, exemplar materials, and facilitator support is available (Brown, Bokor, Crippen, & Koroly, 2014). Most RETs in fact articulate the goal of “helping (teachers) translate their research experiences and new knowledge into classroom activities” as this outcome is required by the National Science Foundation which funds many RETs (Herrington et al., 2012).
Recognizing that teachers do adapt materials for their local context and have the associated knowledge and skills to do so, the next step is considering teachers as designers actively engaged in the purposeful and goal-oriented design of learning experiences for their students and embraces the “role of the teacher in the implementation of curricular and instructional innovations” of their own design (Squire et al., 2003, p 470).

**Teachers as Designers**

Scholarship on teachers as designers is emerging and currently most productive in the area of technology-enhanced learning. Additional international studies have been recently published considering country-wide curriculum reform and engaging teachers in design teams to redesign K-12 courses. Drawing from this research base, there are three main themes of empirical work concerning teachers as designers: the knowledge teachers need to design productive learning experiences, the teacher’s motives for designing innovative lessons for students, and the support needed to promote teachers as designers (Kali et al., 2015). Kali and colleagues depict these themes as a parts of an integrated whole. Their model specifically included studies in technology-enhanced learning, however these themes are frequently acknowledged in work surrounding professional learning and particularly in assisting in-service teachers to adopt new teaching practice.

An important distinction must be made between the construct of instructional design as it is broadly applied to the field of education and teachers as designers as operationalized in this investigation. “Instructional design is a system of procedures for developing education and training programs in a consistent and reliable fashion. Instructional design is a complex process that is creative, active, and iterative.”
It is a systematic approach that “implies an analysis of how its components interact with each other and requires coordination of all activities….a single teacher can create major incongruities among goals, strategies, and evaluation by not using systematic thinking.” (Gustafson & Branch, 2002, p. 18).

Instructional design considers learners generally and is not as contextually based as is the case with teachers as designers creating learning experiences specific to the needs of their students. Indeed, Richey and colleagues (2001) describe a key potential difference between a traditional instructional designer versus a teacher as designer: an instructional designer is not typically the instructional deliverer. However, these two roles can be held by the same person, and in this study, teachers assume the role of designer and deliverer in the role of teacher as designer. In this study, teacher as designer is operationalized as a practicing educator who utilizes design principles and embodies professional teacher competencies as they purposefully design learning experiences best suited for their unique classroom context.

**Conceptual Framework**

The conceptual framework for this study draws from the work of Huizinga (2014) to consider design expertise as a complex set of knowledge and skills (Figure 2-1). Huizinga describes two general types of design expertise needed to successfully enact a design process. Generic design and process expertise refers to the skills needed for enacting team-based design processes in general; specific design expertise refers to the knowledge and skills required for developing curricula. Huizinga (2014) described the generic design and process expertise as those skills that are behaviorally-based and less likely to be modified or directly impacted by professional development.

Exploration of generic design and process expertise as described by Huizinga (2009)
are not applicable to this study as they were specific to teacher design teams and reflect the interpersonal skills needed for team-based design. This study will focus on specific design expertise and be referred to simply as design expertise.

As described by Huizinga (2009, 2014), specific design expertise encompasses the following categories of professional knowledge and skills:

1. **Curriculum design expertise** refers to the knowledge and skills required to enact curriculum design operationalized in specific tactics of analysis, design, development, implementation, and evaluation activities (Gustafson & Branch, 2002) as a) formulating problem statements, b) generating ideas, c) designing systematically, d) underpinning design decisions, e) implementing the designed curriculum materials in practice, and f) planning and conducting formative and summative evaluation (Huizinga, 2014);

2. **Subject matter knowledge** ensures curriculum materials represent accurate, relevant, and current content;

3. **Pedagogical content knowledge** is a unique knowledge base held by teachers that allows them to consider the structure and importance of an instructional topic, recognize the features that will make it more or less accessible to students, and justify the selection of teaching practices based on student learning needs (Gardner & Gess-Newsome, 2011); and

4. **Curriculum consistency expertise** includes attention to internal consistancy as well as external consistancy, taking into account curricular coherence with multiple levels of guidelines from the classroom expectations to national standards (Huizinga, 2009).

Consistent with Huizinga’s findings, in this study, curriculum consistency expertise is combined with curriculum design expertise as the teachers must align their instructional episodes with local pacing guides and district guidelines as well as state-mandated content standards while attending to their instructional goals. Additionally, the process of purposeful design necessitates internal consistancy. This combined construct will be referred to in this study as curriculum design knowledge (CDK) and this form of knowledge is operationalized as the knowledge and skills required to enact the design
of learning experiences which are consistent with local and national education contexts using a systematic design approach.

The resulting integration of knowledge types (subject matter knowledge + pedagogical content knowledge + curriculum design knowledge) is expressed through the construct design expertise considered in this study to be the required skills and knowledge needed to purposefully design quality curriculum materials and learning experiences for the science classroom. Figure 2-2 depicts subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge leading to the resulting design expertise that forms the conceptual framework for this study. The lack of research on design expertise and teachers as designers suggests this is an area for exploration and development. This study posits that the process of increasing design expertise in practicing educators occurs primarily through professional development, therefore an exploration of the literature regarding best practices of professional development for science teachers as well as the evolution of the purpose and models of professional development including the theory of action for this study is considered next.

**Professional Development for Science Teachers**

Teacher professional development is a broad term that encompasses a range of activities and expectations and similarly the accompanying literature is quite extensive. Little (1987) described professional development as “any activity that is intended partly or primarily to prepare paid staff members for improved performance in present or future roles in the school districts” (p. 491). Additionally, professional development incorporates many forms of teacher learning through various activities designed to enhance the professional knowledge, skills, and attitudes of teachers with the goal of improving the learning outcomes of their students (Guskey, 2003). Some researchers
include accidental and informal events in their description of PD, considering PD to be an ongoing and life-long activity (Borko, 2004) while others restrict the definition to purposefully designed learning episodes to bound their study (van Driel, Meirink, van Veen, & Zwart, 2012). The following section will focus on the latter interpretation of PD, concentrating on the structured activities designed by a PD facilitator with the intention of enhancing professional knowledge and skills of teachers with the goal of improving student learning outcomes.

Looking at teacher learning holistically, it can be difficult to discern the impact of extended professional development programs (those which are intentionally designed and goal oriented) from everyday learning experiences and activities (those which are accidental and informal). To address this research issue and avoid comparing different types of activities, there is a general consensus of best practices in professional development, or a set of core features, that enhance professional learning (Desimone, 2009; Garet et al., 2001). Although each type of professional learning can be categorized such as a summer institute or a staff development meeting, it is the activity structures and supports that take place within these categories that define and determine if the professional development experience facilitates teacher learning and if the PD is considered “high-quality” and/or “effective.” These terms are frequently used in the No Child Left Behind Act (2002) which called for high-quality professional development for teachers which is “designed to improve instruction and assessment, enhance the ability of teachers to understand and use curricula, based on scientifically based research demonstrating the effectiveness of the PD in increasing the subject matter knowledge, teaching knowledge, and teaching skills of participating teachers,
and is of sufficient intensity and duration to have a positive and lasting impact on the teachers performance in the classroom” (115 STAT. 1698, NCLB, 2002). Taken together, high-quality professional development would cause a change in teacher knowledge, skills, and beliefs resulting in a positive change in teacher practice which can be quantified by an increase in student learning. Work by Kennedy (1998) supported this supposition of the effectiveness of PD by demonstrating that students of teachers who had participated in a PD program indeed showed increased achievement and studies since have endeavored to understand what supports should be in place to facilitate teacher learning that can be translated into classroom practice to improve student learning outcomes.

**Critical Features of Effective Professional Development**

Desimone (2009) asserts that it is these core features generally agreed upon in the research literature that should serve as the focus of impact studies of professional development and accordingly, these are the features that will be elaborated in this study. These five core features include: content focus, active learning, coherence, duration, and collective participation.

**Content focus**

The content focus is considered the most influential feature of a professional development activity. This follows from previous work which suggested that a teacher’s content knowledge is related to the strategies employed in the classroom (Cronin-Jones, 1991) and the more comfortable teachers are with the subject matter, the more likely they are to engage in inquiry-based teaching practices (National Research Council, 2000). These findings contribute to the implicit model of the purpose of professional development as depicted in Figure 2-3 (Clarke & Hollingsworth, 2002):
professional development leads to changes in teacher knowledge, skills, and beliefs, which are then translated into changes in teacher practices resulting in increased student achievement (Crippen, Biesinger, & Ebert, 2010). This general view is supported by empirical research as well. PD activities that promote teachers’ subject matter knowledge, particularly in conjunction with students’ understanding of the content, directly influence teacher knowledge and skills which are correlated with increased student achievement (Kennedy, 1998). Kennedy (1998) showed that student achievement in math was related to the teacher’s engagement in content-rich professional development and that improving and deepening teachers’ knowledge and skills in science was a main outcome of PD. Similarly, in a study published in *Science*, Silverstein and colleagues concluded that students of teachers who participated in content-focused research experiences achieved higher standardized test scores on the New York State Regents science examination. They considered the scores of students from the year before teacher participation and the years following and compared them to non-participating teachers and found that after participation, students passed at a higher frequency (Silverstein, Dubner, Miller, Glied, & Loike, 2009). The program studied incorporated multiple PD best practices, however, it was the focus on increasing content knowledge and laboratory and research skills that were the aim of the program.

While student performance is more difficult to measure and consequently represented by fewer empirical studies in the published literature, increased teacher knowledge and skills is related to increased student learning. Wayne and colleagues (2008) suggest that due to the high cost of measuring student achievement with appropriate measures, the focus of PD, particularly small PD programs, should be
increasing teacher knowledge, either teacher content knowledge or pedagogical content knowledge (Wayne, Yoon, Zhu, Cronen, & Garet, 2008).

The importance of content focus as a core feature of professional development was also revealed in large-scale studies. Teachers self-report the importance of the professional development program to focus on content (Garet, Porter, Desimone, Birman, & Yoon, 2001). This is the feature of PD that science teachers rate as the most important component and cite as being the primary reason for selecting PD opportunities (Bokor & Crippen, 2016; Devore-Wedding & Thomas, 2016). In the study by Bokor and Crippen (2016), one teacher commented “Content keeps you fresher” referring to her priority of attending content-focused PD programs. Between the empirical studies that point to student achievement and teacher perceptions, content focus is an influential feature of professional development.

**Active learning**

Consistent with current understanding of learning and modeling best teaching practices, the professional development experience should engage teachers in active learning rather than passive transmission of information through such methods as lecture. Active learning allows learners to engage in the learning process as they “understand complex subject matter and are better prepared to transfer what they have learned to new problems and settings” and emphasizes individuals taking control of their own learning (Bransford, Brown, & Cocking, 1999). Through active learning, individuals engage in activities that promote higher order thinking skills such as analysis, synthesis, and evaluation. For example, engaging teachers in first-person experiences through active participation in laboratory experiments (Brown et al., 2014; Gess-Newsome, 1999b), classroom observations with reflection and feedback (Borko,
Coherence

Professional development activities should also promote coherence. This construct has dual meanings in the PD literature: 1) coherence between teacher learning within the professional development activity and the teachers' beliefs and knowledge as well as 2) consistency between the content of the PD activity and reforms and policies from school to national level (Penuel et al., 2007). Both of these interpretations of coherence are evident in the study of a large-scale professional development project in one school district in New York City which instituted a comprehensive, district-wide effort to improve instructional practice and resulting student achievement of its 22,000 students (Elmore & Burney, 1997). All K-12 teachers engaged in similar professional development activities alongside principals, creating coherence between the PD and the practices of all teachers and administrators in each school, attending to the second interpretation of coherence. However, there was also turnover in administration and teaching staff as those whose beliefs and knowledge did not align with the new PD initiative were “counseled out” (Elmore & Burney, 1997, p. 6). Their study represents one situation of PD that is quite different from most TSP PD programs which do not address an entire school district in the comprehensive manner addressed by Elmore & Burney, but rather work with teachers from different schools and often different districts and states. Coherence can be particularly challenging to achieve when teachers with varied knowledge and experience from different local
contexts participate in professional development activities, as is often the case with nationally funded TSP programs. Rivet (2006) found that each teacher’s personal (interpretation one) and contextual alignment (interpretation two) with the PD program impacted their adoption of the PD innovation; if they align, they are more likely to embrace the goals of the PD program (Lumpe, Haney, & Czerniak, 2000). A confounding issue to coherence for national TSP PD programs is the expectation of alignment with the Next Generation Science Standards (NGSS Lead States, 2013). This is particularly relevant to the TSP PD program in this study situated in the state of Florida which has not adopted NGSS nor have they fully embraced the language of the Framework for K12 Science Education (National Research Council, 2012).

**Duration**

The duration of the professional development activity impacts effectiveness; changes in teacher content knowledge and pedagogical practices are best accomplished through activities that are spread over time (i.e., more than one instance) and require several hours (Cohen & Hill, 2001). There is not a specific length of time that is advocated, however sustained interaction over several meetings seems to be more effective than single episodes (Garet et al., 2001) and longer engagement seems to have a larger impact. Yoon and colleagues found that PD programs less than 14 hours in length demonstrated no significant effect whereas those programs with 30 or more hours resulted in significant effects on student achievement (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). Duration and intensity of a PD program has been linked to higher math achievement in students whose teachers participated in extensive math training (Kennedy, 1998). Dresner and Worley’s 2006 study of the six-week Teacher in the Woods RET concluded that long-term changes to practice are connected to duration
and time span and “Adequate time must be allocated for science teachers to be immersed in the world of real science practice as a form of professional renewal” (p. 12) as well as allowing teachers to engage in the inquiry practices of science and authentic research. Extended PD is more likely to afford learning opportunities needed for integration of new knowledge into existing practice (Brown, 2004). Similarly, Supovitz and Turner (2000) found longer durations of PD were needed to create changes in science classrooms that they described as “investigative cultures” which fostered inquiry-based learning.

**Collective participation**

Collective participation embraces the notion of social constructivism and group learning and can serve as a form of teacher learning between teachers with common interests (e.g., grade level, school, subject) (Borko, 2004; Desimone, 2003; Loucks-Horsley, Hewson, Love, & Stiles, 1998). Some researchers refer to this critical feature of PD as collegiality and the professional community that develops between like-minded individuals both within the time span of the formal PD program and informal relationships that continue (Dresner & Worley, 2006). The opportunities to share experiences with others in similar situations (Van den Berg, 2002), especially for teachers who may feel isolated in their school context, is a powerful source of teacher learning (Desimone, 2003). Bokor and Crippen (2016) also identified that teachers return to PD programs coordinated by the same center due to the positive interactions with like-minded individuals. In a case study analysis of serial attendees, several mentioned the collegiality and informal sharing among others with similar interests and experiences as being a motivating factor for PD participation (Bokor & Crippen, 2016).
Certainly, all professional development activities do not emphasize each of these critical features equally and the resulting published research may focus on one or more features in relation to teacher learning, changing practice, or student outcomes. This leads to difficulties for researchers trying to establish empirical evidence of what constitutes effective professional development in general. Desimone (2009) and Wayne and colleagues (2008) have suggested some research ideas to move the field of professional development forward.

**Models of Professional Development**

The purpose of professional development is to foster teacher learning and professional growth (Clarke & Hollingsworth, 2002). The models of how this process occurs have changed as our understanding of teacher learning has deepened. Early forms of professional development were based on a deficit model aimed at improving prescribed knowledge or skills in “one-shot” workshops (Guskey, 1986). These early PD programs followed the implicit model depicted in Figure 2-3, portrayed as a linear process, or causal chain, from PD intervention to student learning outcomes (Clarke & Hollingsworth, 2002). PD was done to the teacher and assumed teacher change would occur to adopt the desired knowledge, skills, or beliefs.

Guskey (1986) suggested a different model that placed the agency with the teacher and engaged them as active learners and participants in their own professional growth. Guskey's (1986) model places changes in teacher beliefs at the end of the model and only after teachers have seen positive student outcomes. While this was a step toward recognizing that teachers may not immediately change their beliefs, it still suggested a strictly linear pathway. Clarke (1988) put forth a model that retained Guskey’s sequence, but placed it in a cyclical fashion and allowed entry from any part of
the cycle. This recognized that not all teachers enter the process of learning at the same point each and every time. Further work led to the development of the Interconnected Model of Teacher Growth (IMTG) which retained categories similar to Guskey’s called domains which encompass the teacher’s world: the personal domain (teacher knowledge, beliefs, and attitudes), the domain of practice (professional experimentation), the domain of consequence (prominent outcomes), and the external domain (sources of information, support, resources) (Clarke & Hollingsworth, 2002). The IMTG is arranged in a cyclical fashion allowing entry at any point and interaction between domains linked by mediating processes of reflection and enactment (Figure 2-4). The IMTG model of professional growth provides a more accurate perspective of teacher learning and the interactions between different elements of the PD environment, the teacher’s local context, and the teacher’s knowledge, beliefs, and attitudes. The evolution of professional development models is important as it informs the model used in this study. However, we must be cautious with our interpretation of these models. Change may occur in one part of the model, but not necessarily the entire system. For example, teachers may change their beliefs but not change their practices (Opfer & Pedder, 2011).

To facilitate the comparison of findings from different programs and a call for more rigorous professional development research, Desimone (2009) proposed the use of a common conceptual framework as the foundation of PD studies to better understand the role professional development activities have on teacher and student outcomes. The pathway model proposed by Desimone (Figure 2-5) is based on previous models (Clarke & Hollingsworth, 2002; Guskey, 1986). Desimone retains the
simple linear structure of Guskey’s model and returns to the implicit model of PD and the definition of professional development as a planned process that promotes teacher learning through various activities designed to enhance the professional knowledge, skills, and attitudes of teachers with the goal of improving the learning outcomes of their students. However, unlike the original implicit model, Desimone’s pathway model accommodates entry at any point, specifically includes the five critical features of PD, and considers the importance of context as exerting force on the entire system. The pathway model includes four constructs: the five critical features of professional development activities; increased teacher knowledge, skills, beliefs, and/or attitudes; change in teacher practice; and improved student learning. The constructs are arranged in a linear fashion, with bidirectional arrows between, indicating the interplay between each construct and suggesting the path from PD to increased student outcomes is not necessarily a linear route, but rather unique for each learner and experience through personal growth and changes in beliefs (Clarke & Hollingsworth, 2002; Guskey, 2002).

Additionally, Borko (2004) described mediating and moderating factors, which she collectively referenced as the context, that exert pressure across the entire pathway and suggested it is the context that has the most impact on changes in teacher knowledge through professional development activities.

The TSP PD in this study is situated within Desimone’s pathway model and directly addresses the first three constructs: critical features of PD; increased teacher knowledge, skills, beliefs, and/or attitudes; and change in teacher practice. The fourth construct, increased student learning, is assumed based on the pathway’s causal nature linking the constructs such that “teachers experience effective professional
development; professional development increases teachers’ knowledge, skills, attitudes, and beliefs; teachers use their new knowledge, skills, attitudes, and beliefs to improve instruction and/or their approach to pedagogy; and instructional changes foster increased student learning” (Desimone, 2009, p. 184-185). The pathway model (Figure 2-5) is also consistent with the logic model for the PD program in this study as suggested by Hill and colleagues such that the TSP PD program activity structures lead to changes in teacher knowledge of biomedical concepts and laboratory skills which leads to changes in classroom instruction through the creation of a new curricular unit which increases student understanding and appreciation for biomedical science (Hill, Beisiegel, & Jacob, 2013).

As the theory of action for this study is situated within a TSP, it is important to understand the history and purpose of TSPs generally and more specifically the types of partnerships between teachers and scientists. TSPs can be fruitful opportunities for all parties, however they are also subject to several challenges.

**Teacher-Scientist Partnerships**

A teacher-scientist partnership is a collaboration between teachers and scientists with the common goal of improving K-12 science education, often through sharing knowledge and expertise from each respective field that results in the creation of new science learning experiences (Tanner et al., 2003). The potential benefits of the collaboration can include deepening content knowledge and understanding of the practices of science for teachers while scientists gain a greater appreciation for the K-12 education system and new insights into pedagogical methods and student learning applicable to their own practice (Tanner et al., 2003). The degree of collaboration between the two parties of the teacher-scientist partnership varies depending on the
goals of the stakeholders. Within the partnership, teachers are defined as members of the K-12 teaching profession while scientists include those individuals engaged with science inquiry at the post-secondary level and includes graduate students, post-doctoral fellows, faculty, and research associates.

The National Science Foundation (NSF) has a long history of supporting scientific literacy through formal interactions between scientists and teachers via funding of teacher institutes starting in 1954. Interactions between scientists and teachers have typically been limited and one-directional. For example, the aim of the NSF teacher institutes in 1954 was to deliver content to educators and the entry of scientists into precollege education through NSF-funded curricula projects featured scientists developing curricula and science content for teachers to directly implement (Rudolph, 2002). While robust and financially well supported during their onset, formal interactions between scientists and teachers including institutes and curriculum projects were terminated in the 1970s when NSF’s priorities were re-organized to exclude K-12 science education and scientists were not encouraged to participate in K-12 activities.

However, recent initiatives sponsored by NSF [e.g., Research Experiences for Teachers (RET), Math Science Partnerships (MSP)] and NIH (Science Education Partnership Award) as well as other foundations (Howard Hughes Medical Institute) and government agencies (e.g., NOAA, USGS) are in response to renewed calls for reform in science education and have increased the role research scientists are playing in science education (National Research Council, 1996). Researchers’ participation in K-12 activities serves multiple functions, not the least of which is to communicate current research and scientific practices as emphasized in A Framework for K-12 Science
Education (NRC, 2012) and Next Generation Science Standards (NGSS Lead States, 2013) but also to introduce potential members of their community of practice (Wenger, 1998) to authentic scientific inquiry and to stimulate interest in the diversity of science careers as well as foster scientific literacy for all. For extended interactions, such as RET apprenticeship programs, the situated nature of the experience facilitates learning as the teacher is immersed in the authentic practices of the research laboratory (Brown, Collins & Duguid, 1989).

Engagement in TSP programs is a social construction that builds on the assumptions, prior knowledge, and experiences of each person involved in the activity. It is a social interaction that creates meaningful learning between scientists and teachers within a zone of proximal development (Vygotsky, 1978) as more knowledgeable individuals (scientists) assist the developing understanding of learners (teachers) to create meaning that increases scientific literacy and engagement with science. Equally important, the teacher facilitates the researcher’s understanding of how to communicate science to different audiences thereby refining the researcher’s perspective about teaching and learning. Within TSPs, both scientists and teachers fill the roles of expert and novice through mutual learning.

As described previously, relationships between teachers and scientists have traditionally been unidirectional as scientists may assume the task of sharing their specialized knowledge as a means to fulfill funding requirements or service for tenure. Similarly, teachers may enter the relationship as a way to gain new instructional resources, identify a role model for students, or speaker for the classroom (Tanner et al., 2003). Without mutual learning and understanding between parties, a TSP is not a
collaborative effort and opportunities to learn from each other are lost. Although TSPs can be fruitful, there are potential barriers to successful partnerships. While there are commonalities between the scientist and teacher professions such as interest in science education and passion for scientific literacy, obstacles stemming largely from the extreme differences in context including the language used in each, resources available, and learner expectations, which Houseal (2010) referred to as cultural differences, can create an impasse. Tanner and colleagues (2003) describe this notion as well with the use of Venn diagrams to illustrate the “common ground” and “uncommon ground” between scientists and K-12 educators and suggest the “hybrid scientist educator” to facilitate interactions between partners. A facilitator experienced in both the science world of higher education and the K-12 classroom can greatly enhance a partnership, providing the middle ground between the two worlds and helping facilitate a productive and mutual learning relationship while establishing a trusting relationship with each of the partners (Tanner et al., 2003). In the work by Houseal and colleagues of a student-teacher-scientist partnership, the facilitator role was crucial for continued success of the program during the school year: although the scientists could devote time during the intensive summer field camps, the facilitator ensured seamless implementation of school-year interactions with students by providing on-going year-long support (Houseal, 2010; Houseal, Abd-El-Khalick, & Destefano, 2014). Similar findings were made during studies of programs from the site of this study. An affordance that program participants cited during a follow-up study of translation of a two-week professional development program into classroom practice was that of on-going support provided by the program coordinator (Brown et al., 2014). Serial attendees to university-
based center PD programs also commented on the importance of the coordinator or facilitator who evoked feelings of comfort in the university setting and working with science researchers (Bokor & Crippen, 2016). There is limited scholarship on the topic of facilitators however, as often the facilitator or coordinator of the PD program is also the researcher.

Teacher-scientist partnerships can take many forms including extended research opportunities situated in the scientist's research laboratory or single day classroom show-and-tell activities by a visiting scientist. Within the spectrum of TSP PD programs, there is limited scholarship regarding the goals, structure, and outcomes of the programs (Klein-Gardner, Johnston, & Benson, 2012) and limited description of the TSP PD programs (Houseal, 2010) particularly when the TSP is funded via a science discipline grant (e.g., NSF RET, NIH SEPA). In content-driven TSP PD programs, other forms of teacher knowledge, such as pedagogical knowledge and pedagogical content knowledge, may be minimized (Schuster & Carlsen, 2009). With continued calls for high-quality professional development for science teachers (Garet et al., 2001), scientist participation in science teacher professional development activities (NRC, 1996), and funding incentives for scientists to engage with broader audiences (NSF, 2016), there is a need to better understand how to develop TSP PD programs that build the knowledge and skills needed to support teachers as designers of new learning experiences for their classroom and effectively translate current science findings to their students.

Recent scholarship has begun to consider TSP programs, particularly RETs, more deeply and address the lack of connection between the authentic research experiences and meaningful design of classroom materials (Herrington et al., 2012).
Example studies follow, but generally in these studies, scholars have found that the inclusion of and wrap-around support of specific pedagogical components such as professional learning communities (PLC, Miranda & Damico, 2015), coursework and materials development (Herrington et al., 2012), and action research (Darwiche, Barnes, Barnes, Cooper, Bokor, & Koroly, under review) facilitate translation of RETs into inquiry-based classroom practices and result in increased student achievement (Silverstein, Dubner, Miller, Glied, & Loike, 2009). By explicitly addressing the professional competencies and knowledge of science teachers as part of a PD program, teachers have successfully translated TSP experiences into classroom practice.

Miranda and Damico (2015) report on a modified RET-PLC program that coupled a six-week RET experience with a school-year follow-up PLC. Teachers participating in this particular program were focused exclusively on science research during the summer and the process of inquiry within an authentic laboratory setting. At the conclusion of the six-weeks, each teacher presented a twenty-minute PowerPoint-based research presentation to share the findings of their summer research projects and suggest implications for the classroom. Teachers were then presented the opportunity to continue their interactions with the science education researchers and fellow teachers through a professional learning community to meet once a month for six months during which they would share ideas and progress toward developing 5E lessons related to their research experience. Teachers were compensated for summer participation and then separately for PLC involvement. The fourteen teachers continuing on with the PLC were able to translate aspects of their research experience into their classrooms, although the level of inquiry-based teaching and change in practice was
limited (7 of 14 teachers) as measured by classroom observations and use of the Reformed Teaching Observation Protocol pre and post participation. However, these teachers were confounded with not just translating the content, but rather focusing on the transfer of inquiry-based practices based on the assumption that by engaging in authentic science necessarily causes a change in one's understanding of the nature of science and inquiry practices and as a result, 10 of 14 expressed difficulties incorporating inquiry-based teaching. Although the authors suggest that more activity structures and design supports should be in place for teachers to translate the content and practices, they do not suggest the explicit inclusion of these features during the six-week research experience.

Similarly, a study by Herrington and colleagues (2012) considered the development of inquiry-based materials as complementary to an RET, consisting of wrap-around course work pre and post summer RET thereby supplementing the RET program. Teachers in the Target Inquiry program were engaged in a seven-graduate course series in chemistry education that included the RET program, materials development, and action research. Results from the Target Inquiry program indicate it is effective in teachers translating their research experience into classroom practice and the resulting teaching modules are of higher quality than a comparison set of chemistry modules developed in other RET programs. These results are encouraging, however the high cost of this program presents a limiting factor along with the selection bias of the teachers who must dedicate three years to the Target Inquiry program.

To offer a contrast to the traditional RET program with sustained interaction (as required by NSF), summer institutes with on-going support can provide another means
of fostering teacher-scientist partnerships and the translation of current research and practices into the science classroom. During these two-week intensive summer programs as described by Brown and colleagues (2014) and Darwiche and colleagues (under review), teachers participate in multiple research experiences and activities with research faculty and graduate students and are tasked with translating some component of the program into their classroom. Teachers are provided support from their colleagues, program staff, and partnering scientists as they draft a presentation on the final day of the summer institute. Teachers are then expected to implement their proposal during the school year and return to the university to share their outcomes. Program staff supports their implementation through on-site assistance and materials and supplies as requested.

Dresner and Worley (2006) state, “Teachers need to know both the subject matter and how students can best learn the subject. Science teachers rarely receive training in both science content and process” (p. 9). These example studies present options for combining science content and science inquiry with the outcome of a RET or summer institute inspired and teacher-created classroom learning module but also suggest that there is not yet one best formula.

**Types of Teacher Knowledge**

Central to the notion of teachers as designers is the knowledge that professional educators must have and be able to apply in order to design effective learning experiences for their students. Many scholars have described different types of teacher knowledge, building upon prior work by further defining discrete knowledge types or collapsing similar types of knowledge into broader typologies. Shulman (1987) described seven types of knowledge: subject matter knowledge, pedagogical
knowledge, pedagogical content knowledge, curriculum knowledge, knowledge of learners, knowledge of education context, and knowledge of education goals. Within Shulman’s categorization, a teacher’s context knowledge of the classroom setting and students is considered pedagogical knowledge.

Grossman (1990) reorganized Shulman’s seven types of knowledge into four and elaborated on the description of each to include: subject matter knowledge, general pedagogical knowledge, pedagogical content knowledge (includes knowledge of students' understanding, curriculum, and instructional strategies), and knowledge of context (similar to Shulman’s education context). In considering types of teacher knowledge that needed to be supported in educative materials, Davis and Krajcik (2005) described content knowledge, pedagogical knowledge, and pedagogical content knowledge (PCK). In the design of TSP PD programs, each of these knowledge domains needs to be considered as well. It is these three main types of knowledge—content knowledge or subject matter knowledge, pedagogical knowledge, and pedagogical content knowledge—that have been the foundational categories in education research of late and are elaborated below.

Subject matter knowledge (SMK) is the discipline-specific knowledge a teacher must have to help students understand the subject. Often, subject matter knowledge is considered the most important type of knowledge as previous studies have shown that increased teacher content knowledge is the largest predictor of student learning gains (Kennedy, 1998). Pedagogical knowledge (PK) forms the foundation for good teaching practices and includes the “principles and strategies of classroom management and organization that appear to transcend subject matter” (Shulman, 1987 p. 8).
Pedagogical content knowledge (PCK) is the broad construct that describes the knowledge teachers need to instruct students in a particular content area. It is an amalgamation of content and pedagogy in a specific context (Gess-Newsome, 1999a, 1999b). For science teachers, PCK includes knowledge of science specific strategies, various ways to represent content, and students’ thinking about science ideas (Magnusson, Krajcik, & Borko, 1999). This construct is perhaps the most difficult knowledge type to measure. Unlike SMK and PK, which can be assessed and standardized through observations and examinations, PCK is socially constructed and assessed according to the accepted teaching practices and content knowledge at a particular moment (Gardner & Gess-Newsome, 2011; Loughran, Mulhall, & Berry, 2004).

An additional construct related to the knowledge typologies is pedagogical design capacity, or the ability to perceive and mobilize personal and curricular resources (Brown, 2002). This construct must be explored to differentiate this study from that of Brown (2002) who uses similar terminology (e.g., teachers as designers). As described below, pedagogical design capacity is not a new construct, but rather is part of pedagogical content knowledge and does not truly engage teachers as designers of innovative materials as this study investigates.

**Pedagogical Design Capacity**

Research in science education has explored a notion related to teachers as designers in the context of in-service teachers using educative curricular materials (Brown, 2002) and pre-service teachers modifying inquiry lessons (Forbes & Davis, 2010). Brown (2002) describes the construct pedagogical design capacity (PDC) as a teacher’s ability to perceive and mobilize personal and curricular resources. Forbes and
Davis (2010) described the design capacity of pre-service teachers to modify existing curricular resources into more inquiry-based instructional plans as part of their teacher preparation coursework. Further work by Davis and colleagues followed elementary teachers utilizing “educative, inquiry-oriented science units” on a technology-mediated learning environment for both pre-service and new practicing elementary teachers (Davis, Beyer, Forbes, & Stevens, 2011). According to Shulman’s (1987) and Grossman’s (1990) definitions of PCK, the construct of pedagogical design capacity falls within pedagogical content knowledge which specifically addresses a teacher’s knowledge and use of resources to enact an instructional episode. Missing from the studies of pedagogical design capacity is the articulation of purposeful design initiated by the classroom teacher. Because of this absence, the construct of pedagogical design capacity is considered part of pedagogical content knowledge in this study. Studies employing PDC have largely focused on enactment, which similar to PCK, captures the tacit knowledge teachers possess to make on-the-fly decisions based on the context and their professional knowledge. The present study is more closely aligned with the notion of an intended curriculum as it considers a teacher’s design expertise to construct an instructional episode rather than focusing on the enactment stage.

The typologies described above articulate the knowledge and skills teachers need as professional educators, however they do not describe how knowledge and skills are translated into practice. The next section considers the related constructs of pedagogical reasoning, professional competencies, and design models as the process of translating teacher professional knowledge into classroom learning episodes.
**Intersection of Pedagogical Reasoning, Competencies, and Design**

**Pedagogical Reasoning**

In addition to the seven knowledge types Shulman described, he also identified pedagogical reasoning, which included the steps a professional teacher uses when planning a learning experience for students. Shulman (1987) described pedagogical reasoning as the process that all teachers undertake as they craft instructional episodes for their classroom. First the teacher must comprehend new content and knowledge personally and transform that knowledge into a manner and level suitable for her students. Through the act of instruction, teachers impart the new content and evaluate the students’ understanding. Finally, the teacher reflects on the educational experience. Missing from Shulman’s construct of pedagogical reasoning (Table 2-1) is a purposeful analysis stage that should inform the transformation of the teacher’s content knowledge into instruction. However, Shulman does include reflection, which can be assumed to shape future instructional episodes.

**Professional Competencies**

Van Merrienboer and Kirschner (2012) define a competency as a “combination of complex cognitive and higher-order skills, highly integrated knowledge structures, interpersonal and social skills, and attitudes and values” (p. 2). Kirschner (2015) argues that all professional teachers should possess five competencies, which he portrayed in cyclical sequence (gather information, analyze and diagnose, determine actions, carry out actions, evaluate) that are not specific to one discipline or tool (e.g. textbooks, whiteboards, computers) in education. These five competencies align well with the steps of pedagogical reasoning described by Shulman (1987) as well as the design cycle or design models commonly utilized in instructional design.
Design Models

Instructional design is based on the notion of a design cycle. There are several versions of the design model, although they are each generally only slight modifications from the broad idea articulated in the first standards describing instructional design competencies (Richey, Fields, & Foxon, 2001). Richey and colleagues (2001) described planning and analysis, design and development, and implementation and management as the key competencies needed for instructional design. These competencies are translated into a cyclical series of steps taken in the process of design. One of the most widely adopted models is the ADDIE model of instructional design: analyze, design, develop, implement, and evaluate (Gustafson & Branch, 2002) with other models being slight derivations. Voogt and colleagues define the following design steps in relation to teacher learning in design teams: problem analysis or definition, design of curriculum products, implementation of the products in practice, evaluation/ reflection on the products, and redesign which combines the design and develop step into one and explicitly calls for the designer to reflect and redesign (Voogt et al., 2011).

Shulman’s steps of pedagogical reasoning assume an ideal state of teacher practice, and as Kirschner (2015) points out, assumes the teacher is a reflective practitioner who constantly and purposefully considers the success of a teaching episode and modifies it for the next iteration based on formative and summative feedback. Pedagogical reasoning, design models, and Kirschner and Van Merriernboer’s five competencies all suggest two important steps: the professional educator analyzes the situation and the professional educator reflects upon and modifies the learning episode and their practice accordingly. However, Huizinga (2009, 2014) found that teachers rarely engage in the first phase of the design cycle - analysis,
and Kirschner critiques the ecology of education that does not allow adequate time for reflection on practice. As this study is bound to the three-week summer TSP PD program, the focus will be on the first three phases of the design cycle (analysis, design, develop), recognizing that the context beyond the University setting is difficult to control or modify yet bears a tremendous impact on a teacher’s ability to engage in the last two phases of the design cycle (implement, evaluate).

Based on the literature review, teachers are novice designers and as such, the professional development experience should be planned to include activity structures and design supports to build their professional knowledge (subject matter knowledge, pedagogical content knowledge, curriculum design knowledge) and scaffold their development of design expertise. The last section of this chapter reviews the literature related to the activity structures and design supports that may contribute to the development of teachers as designers.

**Activity Structures and Design Supports**

Activity structures and design supports are operationalized in this study as the elements within a learning environment (the TSP PD) that scaffold knowledge building and the application of that knowledge to develop an artifact (designed product). There is limited scholarship regarding the activity structures and design supports that should be utilized during a TSP PD program to scaffold the development of teachers as designers of curricular modules. The few published findings provide a starting point for this study by considering the inclusion of the following activity structures and design supports: the five critical features of effective PD, facilitator support, educative materials, and exemplar materials and curriculum templates.
Critical Features of Effective Professional Development

As discussed previously, effective professional development activities for science teachers should embody five critical features: content focus, active learning, coherence, duration, and collective participation. Activity structures and design supports within a professional development program should be planned with these five features in mind.

Facilitator Support

Facilitators assume two distinct but overlapping roles within a TSP PD program. They can serve as a moderator between teachers and scientists, helping to bridge the cultural gap between the two complementary but distinct contexts of the K-12 science classroom and the university research setting. Additionally, facilitators in this study support teachers as designers. The TSP PD program in this study is flexibly adaptive (Trautmann & MaKinster, 2010), providing both just-in-time and structured support to participating teachers as they deepen their professional knowledge and utilize the skills and knowledge of design expertise to craft learning experiences for their students.

Educative Materials

Educative materials are viewed as a way to assist with a teacher’s professional development by providing an opportunity for deepening subject matter knowledge as well as pedagogical content knowledge. Educative materials anticipate the needs of teachers during enactment, building the content and pedagogical knowledge of the practitioner (Davis & Krajcik, 2005) and are crafted to provide background knowledge about a content area while articulating pedagogical practices to assist practitioners with teaching and learning new content.

Educative materials are an effective way to support science teacher learning and classroom teaching (Schneider & Krajcik, 2002; Schneider, 2006). Used within a PD
program, educative materials provide additional scaffolding for teacher learning and can serve as a design support as teachers translate a TSP into classroom practice. Taken together (educative materials and traditional PD), educative experiences enhance teachers’ knowledge which in turn shapes what they do in the classroom leading to improved student learning and understanding of science (Putnam & Borko, 2000).

“ Teachers could be engaged with curriculum materials in ways that generated learning if the materials were integrated into a program of professional development aimed at improving their capacity to teach. In that case, well-designed materials could be a resource for teachers' learning.” (Ball & Cohen, 1996, p. 8). This study utilizes educative materials as a design support and resource for developing curriculum design knowledge and resulting design expertise.

Educative materials have largely been discussed in the context of teacher learning particularly as related to content knowledge and pedagogical content knowledge, but little work has investigated how the structure of educative materials can help teachers develop the knowledge and skills needed to design new learning experiences for their classroom context (i.e., curriculum design knowledge and design expertise). A study by Penuel and colleagues (2011) suggests there may be a correlation. Their investigation of teachers who participated in professional development that utilized educative materials found that those teachers who used the materials during the PD and received explicit instruction on the designer’s rational and pedagogical reasoning in turn designed earth science lesson sequences that were more effective at improving student learning (Penuel et al., 2011).
Exemplar Materials and Curriculum Templates

Inclusion of support features that are directly applicable to the design of curricular products scaffolds teachers as designers. In a study of multiple teacher design teams located in different schools with different facilitators, the incorporation of exemplar materials and curriculum templates had the largest positive impact on design process and products (Huizinga, Handelzalts, Nieveen, & Voogt, 2015). Similarly, by comparing three professional development programs and a control condition, Penuel and colleagues determined that the PD conditions that featured the use of a design template and explicit instruction about the instructional models used in the PD and educative materials, resulted in larger student learning gains (Penuel et al., 2011) and had an enduring impact on teachers’ design of teaching units (Penuel et al., 2009).

Conclusion

This current study of teachers as designers is grounded in the critical features of effective professional development as a foundation to crafting a meaningful and high-quality teacher-scientist professional development program. Incorporating activity structures and design supports will scaffold the development of teacher design expertise as teacher professional knowledge is deepened. Three types of knowledge teachers as designers need are considered in this study: subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge and the integration of these knowledge typologies will be the focus of this study.
Figure 2-1. Teachers’ design expertise overview in teacher design teams (Huizinga, 2009, 2014).
Design Expertise

Subject matter knowledge

Pedagogical content knowledge

Curriculum design knowledge

Figure 2-2. Teachers’ design expertise is represented by the integration of subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge.
Figure 2-3. An implicit model of the purpose of teacher professional development. (From Clarke & Hollingsworth, 2002).
Figure 2-4. The interconnected model of professional growth. (From Clarke & Hollingsworth, 2002).
Critical features of PD:
- Content focus
- Active learning
- Coherence
- Duration
- Collective participation

Increased teacher knowledge and skills; change in attitudes and beliefs
Change in instruction
Improved Student Learning

Context such as teacher and student characteristics, curriculum, school leadership, policy

Figure 2-5. Conceptual framework for studying the effects of professional development on teachers and students (From Desimone, 2009).
<table>
<thead>
<tr>
<th>Model</th>
<th>Stages or Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADDIE approach (Gustafson and Branch, 2002)</td>
<td>Analyze</td>
</tr>
<tr>
<td>Pedagogical reasoning (Shulman, 1987)</td>
<td>Comprehension</td>
</tr>
<tr>
<td>Instructional design competencies (Richey et al., 2001)</td>
<td>Planning and analysis</td>
</tr>
<tr>
<td>Curriculum design expertise (Huizinga, 2009)</td>
<td>Formulating problem statements</td>
</tr>
<tr>
<td>Design cycle (Voogt et al., 2011)</td>
<td>Problem analysis or definition</td>
</tr>
<tr>
<td>Professional competencies (VanMerrienboer &amp; Kirschner, 2012)</td>
<td>Gather information Analyze/diagnose</td>
</tr>
<tr>
<td>Teacher design competencies (Kirschner, 2015)</td>
<td>Gather information about learners Diagnosing/determining what is best for learners</td>
</tr>
</tbody>
</table>
CHAPTER 3
METHODOLOGY

This chapter describes the methodology for this study. The chapter begins with a statement of purpose and a description of the research design. The chapter also provides a description of the research plan, including the context and participants of the study, instruments, data collection, and data analysis procedures.

Purpose Statement and Research Questions

The purpose of this study is to explore how teachers’ engagement with the activity structures and design supports of a teacher-scientist partnership professional development program influences their professional knowledge and develops their design expertise for translating the TSP PD into a learning experience specific to the education goals for their classroom context. The research questions for this study are:

- RQ1: How do the activity structures and design supports of the TSP PD influence subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge?
- RQ2: How do changes in subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge relate to the development of design expertise?
- RQ3: How do participants perceive the activity structures and design supports of a teacher-scientist partnership professional development program affording or constraining their design expertise?

Introduction

Consistent with design-based research (DBR) as a form of inquiry, this study seeks to understand the complex interactions of the designed intervention of a TSP PD and outcomes in an authentic learning context based on empirical research and theoretical considerations of the designed setting and its influence on learning (Barab & Squire, 2004; Design-Based Research Collective, 2003; Hoadley, 2004; Sandoval,
Specifically, using design-based research in this study allows the exploration of teachers’ interactions with the activity structures and design supports of a TSP PD to understand how the designed environment impacts learning and application of knowledge to foster teachers’ curricular design of learning episodes for their students through the development of design expertise. DBR considers the intervention and outcomes—the phenomena associated with this study—to be dependent upon the interaction of numerous contextual factors that advances theory of teaching and learning while addressing practical concerns of implementation for other TSP PD programs (DBRC, 2003).

The TSP PD program at the focus of this investigation combines aspects of a summer institute and an extended research apprenticeship program (e.g., RET) based on previous research and evaluation of CPET’s TSP PD programs. I have served as the program coordinator for the numerous professional development programs offered by CPET, from one-day to multi-week with school year follow-up, and it is my personal experience that motivates this study. The current three-week combination research and curriculum fellowship TSP PD program in this study is the latest DBR iteration, building on previous programs, considering teacher feedback, program evaluation, and outcomes as well as the empirical literature. For example, a previous seven-week, summer-long research experience funded by an NSF grant over five years and working with close to 150 math, science, and technology teachers revealed the length of time was prohibitive for many teachers and the placement in one research laboratory was restricting for some but the accompanying research lectures presented as a morning lecture series before spending the day in the laboratory were well received (Barnes,
Hodge, Parker, & Koroly, 2006). In shorter two-week summer institutes funded by a Howard Hughes Medical Institute precollege award and a NIH Science Education Partnership award which welcomed 198 secondary science teachers between 2008-2013, teachers once again valued the content delivered by scientists and the experience learning new techniques, but wanted to be immersed in authentic research laboratories for extended times and engage in singular experimental topics more deeply (Borgerding, Sadler, & Koroly, 2013; Bokor & Crippen, 2016). Teachers also expressed numerous affordances (e.g., active learning, classroom-ready materials, equipment lockers) and constraints (e.g., pacing guides, classroom contexts, not enough reflection during the program) to translating the TSP PD program into classroom lessons (Brown, Bokor, Crippen, & Koroly, 2014). During formal program evaluations and informal conversations with the teachers, they wanted additional programs offered by CPET, more time to interact with scientists, and an opportunity to focus on biomedical research in one laboratory to better understand the intricacies of authentic science research as well as understand the larger goals of the projects (Bokor & Crippen, 2016). In response to this feedback, two supplemental grants, along with broader impacts components have funded three cohorts of research/curriculum fellows. The fourth cohort was summer 2016, funded by NIH SEPA and was the TSP PD at the center of this study which builds on the 20+ year history of TSP PD programs offered by the same university outreach center as the current iteration—the fourth DBR cycle—of CPET’s Summer Research Experience (SRE) TSP PD model, and it is this previous work, as well as the limited empirical findings, that call for a focused inquiry of how to support teachers as designers through effective TSP PD programs.
Conjecture Mapping

To frame the inquiry, conjecture mapping provides an explicit description of how learning may occur in a particular environment and the interaction of the variables under investigation by suggesting three levels of conjectures that shape the investigation (Sandoval, 2014). Figure 3-1 provides an overview of the three conjectures for this study. As conceptualized by Sandoval (2014), design research investigates the embodiments of the design that are expected to produce mediating processes that result in outcomes. Figure 3-2 illustrates the embodiments, mediating processes, and outcomes for this study.

The overarching construct guiding the investigation is the high-level conjecture that provides rigor and theoretical grounding. The high-level conjecture of this study posits that developing science teachers’ design expertise through a TSP PD program requires providing varied activity structures that support first person authentic science learning (e.g. conversations with researchers, immersion in active research laboratories) and purposeful design support activities in order to enhance teachers’ professional knowledge (SMK, PCK, CDK) and skills for translating the experience into a designed lesson specific to the education goals for their classroom context.

The design conjecture links the embodiments with the generated mediating processes such that if teachers assume and fulfill the implied roles based upon how they are grouped for each PD activity (e.g. experiments, discussion, etc.), fully engage with the design supports (e.g., design tasks, formative evaluation, etc.), and fulfill the program objectives, they will build the necessary professional knowledge (PCK, SMK, CDK) for translating the TSP PD resources for their classroom context. The design conjecture informs research question one.
• RQ1: How do the activity structures and design supports of the TSP PD influence subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge?

The theoretical conjecture is the last conjecture in the conjecture mapping schema, and it connects the mediating processes with the resulting outcomes of the design intervention. In this study, the theoretical conjecture proposes that through the core process (full engagement with TSP PD activity structures and design supports) professional knowledge is enhanced via individual improvement and collective interaction of SMK, PCK, and CDK producing a correlated level of design expertise which is expressed through a design artifact that is purposefully constructed to translate the science content of the TSP PD into a meaningful learning experience for a specific classroom context. The theoretical conjecture informs research questions two and three.

• RQ2: How do changes in subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge relate to the development of design expertise?

• RQ3: How do participants perceive the activity structures and design supports of a teacher-scientist partnership professional development program affording or constraining their design expertise?

The conceptual framework for this study draws from the work of Huizinga (2014) to consider design expertise as a complex set of knowledge and skills, specifically subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge. Conjecture mapping affords a lens to view the learning environment of the TSP PD in this study and provides a scaffold to develop a high-level conjecture (i.e., overarching construct guiding the design experiment); a design conjecture which conveys the connections between the embodiments (i.e., participant engagement with design and activity supports) and the mediating processes (i.e., observable interactions
and artifacts of SMK, PCK, and CDK); and a theoretical conjecture to link the mediating processes with the outcomes (i.e., design expertise exhibited through the creation of a designed curricular product). Articulating these elements allows us to consider the many factors influencing a learning environment in a systematic fashion. The research questions for this study arise from a design-based research paradigm and will be explored through a single case method within an existing TSP PD program.

**Approach**

This design-based research study employed qualitative methods of a single case study (Creswell, 2014) to explore how teachers engage with the activity structures and design supports of a teacher-scientist partnership professional development program to develop their design expertise for translating the TSP PD into a learning experience specific to the education goals for their classroom context. Mixed methods are often used with the design-based research paradigm to provide quantitative measures along with thick description of the context (DBRC, 2003); however, due to the small sample size of this study, only descriptive statistics and non-parametric statistical measures were used to provide a potential lens to view the results and future research. A case study design (Yin, 2013) investigated factors within the bounded process of a single cycle of a TSP PD program. This study considered the teachers collectively as a single case and considered only their experience within the three-week TSP PD. Since it was bounded to the three-week TSP PD, this study did not aim to predict how teachers’ design expertise is influenced by previous experiences nor does it suggest success for implementation and evaluation. These factors (i.e., previous design experience, designed lesson implementation, and designed lesson evaluation) are beyond the bounded nature of this study. By focusing only on the three-week TSP PD program as
the intervention, this allowed teachers’ perceptions of different program structures to be understood and to associate a level of PD effectiveness based on the teacher participants’ design expertise.

Quantitative measures were used at the same time as qualitative measures to provide triangulation for qualitative findings (i.e., daily reflections, storyline approach) or to provide a score as a measure of professional knowledge or design expertise (i.e., subject matter knowledge assessment, pedagogical content knowledge, curriculum design knowledge, design expertise). Repeated measures were used for subject matter knowledge, pedagogical content knowledge, and pedagogical design knowledge to assess changes in professional knowledge from the beginning to the end of the summer TSP PD program. Each teacher’s design product was evaluated using a lesson plan analysis instrument and assigned a numerical score as a measure of design expertise.

Qualitative data sources included a daily reflective journal with evaluative and reflective prompts to consider the immediate value of summer TSP PD program components, field notes to capture descriptive and observational information of the TSP PD program, and semi-structured interviews with each participant to better understand their perceptions and experience as a designer during a TSP PD program. Lastly, as a summative instrument, participants considered the activity structures and design supports holistically using a storyline approach, allowing them to rate the value of each program feature and offer a supporting statement to explain their rating. Qualitative data was triangulated to ensure trustworthiness and rigor.

**Context**

One TSP PD program was explored in this study during the summer, 2016. Table 3-1 lists the activity structures and design supports of the TSP PD program. The specific
TSP PD program in this study is similar to a Research Experience for Teachers in the extended length of the program and the interaction with scientists in authentic research laboratories yet also has elements of a more traditional summer institute. This hybrid TSP PD program called the Summer Research Experience (SRE) invited eleven teachers who had successfully completed a previous two-week biomedical summer institute with school year follow-up to spend three weeks on the University campus for a research and curriculum development fellowship. During the first two of the three weeks (nine weekdays due to the long July 4th weekend), participant pairs were situated in research laboratories and participated in ongoing laboratory investigations for approximately eight hours per day. In addition to his or her immersive laboratory experience, the participants participated in three evening whole-group sessions and individual work sessions intended to facilitate the development of each participant’s professional knowledge and design expertise. During the last week of the program (five weekdays), the participants focused exclusively on curriculum writing. Each participant was expected to design a three to five lesson unit to incorporate into their classroom curriculum based on the TSP PD laboratory experience. The participants presented and submitted their draft curriculum on the final day of the TSP PD program.

**Research Location**

The primary research location for this study is the summer TSP PD program located on the university campus. Participant pairs were placed in six biomedically-focused research laboratories in the Health Science Center. The content focus of the research laboratories as described by the research mentors and their associated University of Florida departments are detailed in Appendix A. Participants were also provided on-campus housing in a residence hall where common space was utilized for
evening sessions and meeting rooms were used for the semi-structured interviews and one-on-one curriculum meetings.

Participants

The participants of this study comprise a convenience sample of high school science teachers who applied for and were selected to attend the TSP PD program. An invitation for applicants for the three-week TSP PD program was emailed to the 198 past program participants from the ICORE and Bench to Bedside Phase I TSP PD programs. Additionally, the 23 participants from the 2015 Bench to Bedside Phase II TSP PD program were invited to apply. The application process was completed via an online form that asked each applicant about their previous TSP PD participation, plans for developing and implementing a new curricular unit, topics they would like to explore, topics they believe their students find challenging, and what instructional practices they employ (see Appendix B). Based on stipulations in the grant, the applicant pool was narrowed using the following criteria: 1) successful completion of a previous CPET TSP PD which included completion of two-week institute, submission of final action proposal and lesson plan, and final report demonstrating successful implementation of their action proposal; and 2) not a previous three-week TSP PD program participant. The original TSP PD program coordinator, TSP PD project Principal Investigator, and myself discussed the remaining applications to reach a consensus based on similar teaching subject (life science related) and grade level (high school) attending to the feature of professional development for collective participation; and diversity of school types and levels of courses to reach a range of student demographics. Twelve teachers were invited to attend the three-week TSP PD program. One participant withdrew shortly before the program began and an alternate could not be placed, resulting in eleven
participants. Each participant was provided a stipend for their summer participation and access to equipment locker loans and program support during the school year. All participants in the TSP PD program were invited to join the study and gave consent at the onset of program activities. (Consent form for UF IRB 2014-U-0558, Koroly PI/Bokor Co-PI, Appendix C.)

The eleven participants invited to attend the 2016 TSP PD program are all high school science teachers (Table 3-2). Ten of the participants have a primary teaching assignment of biology or related life science course; the eleventh participant is a chemistry teacher. Based on my previous experience with similar CPET TSP PD programs, review of program evaluations, and a previous empirical study (Brown et al., 2014), biology teachers have fewer difficulties translating the biomedical-focused PD into classroom practice as the content aligns more easily with the science standards they must address. The one chemistry teacher was able to incorporate content from her previous biomedical summer institute into her curriculum and has been a very enthusiastic participant. Additionally, her dissertation research focused on protein synthesis, so she has a strong foundation in biochemistry. Because of her motivation and demonstrated ability to translate a biomedical PD program into classroom practice, she was invited to attend the SRE.

**Sampling Limitations**

Study participants are self-motivated individuals who choose to apply and attend the TSP PD program. Since they have also previously attended a program coordinated by CPET, the staff selects those most likely to be successful based on prior participation and implementation outcomes. As Brown and colleagues found (2014) in a previous investigation of two cohorts of a CPET TSP PD, all of the TSP PD program participants
encountered affordances and constraints that impacted the development and implementation of their action proposals, however some teachers were more successful overcoming contextual constraints (e.g., limited classroom resources, pacing guides). Since the grant outcomes are measured by successful implementation, those teachers that have demonstrated the capacity to incorporate new ideas are preferentially selected. Another study of the center’s TSP PD programs investigated why teachers return to CPET coordinated programs. Teachers expressed comfort and familiarity with CPET, including the staff, and the desire to produce quality products (Bokor & Crippen, 2016). As such, the study population is not generalizable to all secondary science teachers or to all TSP PD programs. These teachers are self-motivated, high-achieving individuals who are likely to design and implement new learning experiences for their students due to their internal motivation as well as to accomplish the outcomes the TSP PD program staff desire, potentially biasing the study to suggest larger professional knowledge gains and more positive perspectives. Additionally, the participants of this study were selected via convenience sampling: all participants of the TSP PD program were invited to participate in the study.

**Data Collection**

Multiple data sources were used to explore how teachers engage with the activity structures and design supports of a teacher-scientist partnership professional development program to develop their design expertise for translating the TSP PD into a learning experience specific to the education goals for their classroom context. *Table 3-3* provides an overview of each instrument and the associated research question it addressed.
The first research question addressed the design conjecture: How do the activity structures and design supports of the TSP PD influence subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge? To answer this question, subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge were measured with quantitative instruments. The Biomedical Knowledge Assessment, a researcher designed subject matter knowledge assessment, provided a measure of each participant’s biomedical science subject matter knowledge to understand if deeper, broader content knowledge influences design expertise. The PRIME PCK rubric was used to measure pedagogical content knowledge based on teacher responses to a prompt. Curriculum design knowledge was measured using a researcher-developed survey of the participants’ agreement with implementing 15 design elements based on principles of design in published literature. Quantitative Likert-type scale scores and comments from daily reflective journals were also utilized to understand if the participants believed there were changes to their learning, pedagogical practices, and instructional design decisions based on participation in the various activity structures and design supports of the TSP PD program.

The second and third research questions address the theoretical conjecture: How do changes in subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge relate to the development of design expertise? How do participants perceive the activity structures and design supports of a teacher-scientist partnership professional development program affording or constraining their design expertise? To answer the second question, the Science Lesson Plan Analysis Instrument (SLPAI) was used to measure design expertise via a score on each
participant’s final designed curriculum (See Appendix D for curricular template). The subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge (i.e., measures of professional knowledge) gain scores were used as well as the measure of design expertise (i.e., SLPAI score) to determine if there was a relationship between professional knowledge and design expertise. To answer research question three, a storyline reflective approach and semi-structured interviews were employed to understand the perceptions of the teachers as to what features of the TSP PD were most valued in their development of curricular materials.

**Instruments**

**Biomedical knowledge assessment**

Subject matter knowledge (SMK) is the discipline-specific knowledge a teacher must have to help students understand the subject. To measure SMK in this study, a researcher-developed biomedical science subject matter knowledge assessment was administered pre- and post- TSP PD program (see Appendix E). This instrument includes multiple choice and short answer items and was used to assess the level of teacher subject matter knowledge of biomedical science concepts upon entering the TSP PD program, what, if any changes in subject matter knowledge occurred during the program, and how it might be related to design expertise.

A review of the literature did not reveal an appropriate subject matter knowledge assessment of the TSP PD due to misalignment of the content or the grade level. The teachers participating in the TSP PD program are all high school level and some teach advanced level life science courses (e.g., Advanced Placement Biology, Honors Genetics, International Baccalaureate Biology). As such, because they are teaching advanced biology concepts throughout the school year, they typically have deeper
subject matter knowledge in biology upon entering the TSP PD program than the available validated life science assessments which target middle grades, on-level high school grades, or specific topics within biology such as natural selection/evolutionary biology concepts or ecosystems (e.g., Horizon Research, Inc. AIM Teacher Assessments; Misconceptions-Oriented Standards-Based Assessment Resources for Teachers (MOSART) Tests for In-Service teachers from Harvard University; Concept Inventory of Natural Selection by Anderson, Fisher, & Norman, 2002). The additional specificity of the TSP PD program to biomedical science and translational medicine made it difficult to identify a potential instrument. Consequently, a new biomedical science subject matter knowledge assessment (i.e., biomedical knowledge assessment) was developed and used during a pilot study in summer 2015. The development of this instrument for the 2015 TSP PD program and pilot study results are described below.

While the overall focus of the 2015 TSP PD program was biomedical research and many of the experiments and presentations remain the same each year, there is variability in the content based on researcher availability, shifts in national priorities, and changing public interest. In an effort to develop an assessment that would accurately reflect the changing content of the biomedical TSP PD and potentially be used each program year of grant funding, a distal approach was taken in selecting content items for the biomedical knowledge assessment used during the pilot study. The distal approach focused on items that are general biology knowledge and application of concepts that form the basis of biological understanding and more prevalent in biomedical research such as protein synthesis, model organisms, and RNA silencing rather than life science items related to botany or ecosystems. Fifty items were drawn
from the AAAS Benchmarks test database and the Campbell and Reece Biology, 9th Edition test bank by the primary researcher. These items were subject to content review by an expert in biomedical science for alignment to the 2015 TSP PD program content and scientific accuracy of the questions. The pilot biomedical knowledge assessment consisted of 25 items that were administered to program participants on the first day and the last day of the 2015 TSP PD summer institute. After participants completed the post assessment, they were asked to strike through any question they felt was not appropriate or applicable the TSP PD institute and suggest other content items that should be included. Suggestions made by multiple individuals or those items that were well argued for removal have been incorporated into the modified version of the biomedical content assessment. For example, one item from the AAAS test bank had three distractors that were very similar to each other causing the correct answer to be easily discerned. Items that were suggested included items that are related to newer biotechnologies such as gene therapy and personalized medicine and the presentation of case studies or differential diagnosis.

Analysis was completed of the pilot administration of the biomedical content assessment. Reliability testing produced a Cronbach’s alpha of .861 indicating the internal consistency of the assessment is good. A dependent t-test also indicated that there was a significant increase in content knowledge \( (t = 2.168, df = 19, p = .043) \) however, the average gain score was only 1.1 point with a range of gain scores from -3 to +5 for the 20 teachers that completed both the pre- and post-assessment. One factor that might have contributed to a lower average gain was the omission of a module related to protein synthesis due to scheduling constraints as activities preceding the
module went longer than anticipated and severely truncated the time allotted. Several questions on the assessment were related to this particular concept.

The TSP PD program that is the focus of the current study maintains the concentration on biomedical science, but the content of the Summer Research Experience is more variable since participants are situated in a single research laboratory for the program and engaged in a very specific area of biomedical research. The distal measure is still applicable and the most appropriate to address the range of concepts each participant may explore in depth during their laboratory placement. To better assess the deeper knowledge that the participants will have the opportunity to develop and respond to the pilot teachers’ suggestions, an essay style item was selected from a past Advanced Placement Biology exam and graded according to the rubric developed by the College Board for those items. Several of the AAAS test bank items were removed due to ambiguous phrasing or simply being too easy, however, additional questions were not added since suitable replacements were not identified from the Florida Biology End of Course exam practice test bank as was originally intended. This modified assessment consisting of 18 multiple-choice items and one AP Biology free response question was used in this study.

All assessment items were piloted prior to use with the 18 teachers attending the Bench to Bedside TSP PD program in June 2016 to assess usability. All pilot teachers completed pre and post administrations without issue. During the current study, the biomedical knowledge assessment was administered pre- and post- TSP PD program. This measure was used to assess the level of teacher subject matter knowledge upon
entering the TSP PD program, what, if any changes in subject matter knowledge occurred during the program, and how it might be related to design expertise.

**PRIME PCK Rubric**

Pedagogical content knowledge (PCK) is the broad construct that describes the knowledge teachers need to instruct students in a particular content area. It is an amalgamation of content and pedagogy in a specific context (Gess-Newsome, 1999a, 1999b). For science teachers PCK includes knowledge of science specific strategies, various ways to represent content, and students’ thinking about science ideas (Magnusson, Krajcik, & Borko, 1999). In this study, PCK was measured using the PRIME PCK Rubric (see Appendix F). The PRIME PCK Rubric (Gardner & Gess-Newsome, 2011) was developed as part of the multi-year Project PRIME (Promoting Reform through Instructional Materials that Educate) study to examine the change in pedagogical content knowledge of high school biology teachers implementing educative curricular materials following professional development (Schneider & Krajcik, 2002). The PRIME PCK Rubric adopts the view that PCK is an integrative knowledge base composed of content knowledge, pedagogical knowledge, and contextual knowledge and assumes that 1) PCK is topic and discipline specific, 2) PCK exists on a continuum from weak to strong, and 3) PCK can be strengthened and move along the continuum through high quality professional learning experiences.

The PRIME PCK Rubric consists of three categories corresponding to content knowledge, pedagogical knowledge, and contextual knowledge with one to four items within each category for a total of eight items. Based on the quantity and quality of the responses provided by the teacher, each item is rated according to the following scale: advanced teacher knowledge (3 points), proficient (2 points), basic (1 point), or limited
Rubric items were based on a review of the literature. To establish validity and reliability of the rubric for the PRIME project, Gardner and Gess-Newsome (2011) utilized three data sources: teacher written reflections, videotaped classroom instruction, and teacher interview reflections. Inter-rater reliability was established as substantial.

For the purposes of this study, only written reflections were analyzed as a measure of PCK, based on the instrument developed by Gardner and Gess-Newsome (2011). The written reflections asked participants to describe the student and teacher activities during the instruction of protein synthesis and respond to a set of accompanying questions (Gardner & Gess-Newsome, 2011). Measuring PCK within the frame of the three-week TSP PD presents many challenges. PCK is usually measured through a combination of classroom teaching observation, proceeded and/or followed with an interview of the teacher by the observer, and reflection by the teacher regarding the success of a single lesson or unit and modifications for future implementation. These standard approaches to measuring PCK are situated within a classroom and capture the tacit knowledge teachers possess and utilize on-the-fly in response to their students' learning needs. Within the bounded nature of this study of a three-week TSP PD situated on a university campus during the summer, it is not possible to observe, interview, and reflect on enactment since the teachers will not implement their designed curriculum with their students during the three-week program. The PRIME PCK Rubric suggests an alternative approach to approximating PCK (Gardner & Gess-Newsome, 2011). As a proxy of PCK, teachers were given a prompt and asked to describe in detail how they would teach a particular concept. During a pilot with the 2015 TSP PD
program, all teachers were provided a prompt related to teaching protein synthesis at the beginning of the program and then asked to make any changes to their pre-PCK prompt response at the conclusion of the summer institute. The results from the use of this prompt were skewed positively to those teaching more advanced level grades and/or content. Middle school teachers did not have the depth of content knowledge nor the experience teaching the concept of protein synthesis to the level of the AP Biology teachers. However, the prompt is appropriate as it is a standard that high school biology teachers must address and is relevant to many of the studies in biomedical research, whether basic or applied science, which often aim to understand some part of the central dogma from RNA \(\rightarrow\) DNA \(\rightarrow\) protein \(\rightarrow\) trait and work toward developing a therapeutic. During this study with a more homogeneous group of high school teachers, the same PCK prompt for teaching protein synthesis and the associated Florida science standard were used at the beginning and conclusion of the program (Appendix G).

When using the PRIME PCK rubric and reflective prompt, Gardner and Gess-Newsome (2011) caution that “only researchers with high levels of topic specific PCK, or those trained to recognize topic specific PCK, will have success in using this rubric,” (p. 8). Accordingly, protein synthesis was selected as the topic for the PCK reflective prompt for several reasons: 1) it is a benchmark addressed in general biology (SC.912.L.16.5 - Explain the basic processes of transcription and translation, and how they result in the expression of genes); 2) it is tested on the Biology End of Course exam in the state of Florida; 3) it is a topic that several of the laboratory placements address at some level; 4) it is a topic I am familiar with and have written a curriculum to address; 5) my curriculum was used as the model for the TSP PD program; and 6) all of
the participants either currently or previously have taught biology and should be familiar with protein synthesis.

**Curriculum design knowledge survey**

Curriculum design knowledge (CDK) is the knowledge and skills required to enact the design of learning experiences which are consistent with local and national education contexts using a systematic design approach. The features of CDK align with the elements of the design cycle in instructional design and it is this literature that was searched to find a valid and reliable measure of curriculum design knowledge. No suitable instrument was identified, therefore a researcher-developed survey was created for this study. The CDK survey *(Appendix H)* was based upon a literature review of design principles and practices, specifically those used by classroom teachers directly or intended to be used by curriculum development teams in collaboration with teacher partners. Items were adapted from Hardre’s (2003) instructional design knowledge and strategies, Huizinga’s (2014) features of curriculum design expertise, and Reiser, Krajcik, and colleagues’ (2003, 2008) design strategies for developing science instructional materials. All of these design practices have a foundation in the principles of the ADDIE model of instructional design.

Fifteen statements of design principles were adapted from previously published studies as described above and presented in a Likert-type scale from strongly agree to strongly disagree. As this is a new instrument, it was administered in a pre, retrospective, and post fashion to understand how participants view their agreement with the extent they perform the listed design principles. It was expected that participants might feel more confident about their curriculum design knowledge prior to engaging in structured learning sessions (Pratt, McGuigan, and Katzev, 2000), therefore
a retrospective administration of the CDK survey was included. The use of a retrospective survey provides participants a baseline with which to compare their perceived change in knowledge and allows participants to consider their change once they possess a deeper understanding of the principles of design. Additionally, this is a subjective measure and as such Hill and Betz (2005) recommend using a retrospective pretest to assess program-related change.

**Science Lesson Plan Analysis Instrument (SLPAI)**

The resulting integration of knowledge types (subject matter knowledge + pedagogical content knowledge + curriculum design knowledge) is expressed through the construct design expertise considered in this study to be the required skills and knowledge needed to purposefully design quality curriculum materials and learning experiences for the science classroom. To measure the construct design expertise, the Science Lesson Plan Analysis Instrument was used to assess each teacher’s final designed product (see Appendix I).

The Science Lesson Plan Analysis Instrument (SLPAI) was originally developed to evaluate changes in teachers’ practice to a more inquiry-based approach due to participation in a Math and Science Partnership program (Jacobs, Martin, & Otieno, 2008). The SLPAI was based on the Science Lesson Plan Rating Instrument (SLPRI; Hacker & Sova, 1998), which focuses on procedural aspects of lesson planning. Additional elements were included in the SLPAI based on powerful learning environments (Brown & Campione, 1996), student-centered teaching and learning (How People Learn, Bransford, Brown, & Cocking, 1999), assessment and curriculum design approaches (Understanding by Design, Wiggins & McTighe, 2001), and aligned with the Science Teaching Standards of the National Science Education Standards (National
The SLPAI was validated by triangulation with other measures of teacher practice including a researcher-developed teacher questionnaire, the Standards-Based Teaching Practice Questionnaire, and classroom observation analysis using the Reformed Teaching Observation Protocol.

The SLPAI consists of four subscales: Alignment with Endorsed Practices (AEP), Lesson Design and Implementation—Cognitive and Metacognitive Issues (CMI), Lesson Design and Implementation—Sociocultural and Affective Issues (SCAI), and Portrayal and Uses of the Practices of Science (PUPS) with two to seven items within each subscale for 22 total items. Each item is rated according to the following scale: exemplary (2 points), making progress (1 point), or needs improvement (0 point). Each item is also given a weight (1 – 3) based on the importance of that item in relation to the goals of the original program for which the SLPAI was developed. For this study, the original weights were retained and a composite score that reflects the integration of multiple professional knowledge types used as a measure of design expertise. The SLPAI was designed to evaluate multi-day instructional episodes with all materials needed to lead the instruction included in the portfolio, similar to the 3-5 day designed curricular units developed by the teachers of this study. As such, the SLPAI is an appropriate instrument for analyzing the designed curriculum of this study and equating a measure of design expertise.

As discussed above, the SLPAI was developed based on previous work including the Science Lesson Plan Rating Instrument (Hacker & Sova, 1998) and Understanding by Design (Wiggins & McTighe, 2001), influenced by findings in How People Learn (Bransford, Brown, & Cocking, 1999), and aligned to the NSES Teaching Standards.
(NRC, 1999). As such, the criteria outlined in the SLPAI were not considered for their alignment with different forms of professional knowledge, which is the focus of this study. Therefore, to better understand how the different criteria do align with and account for different forms of professional knowledge, the instrument was compared to key measures and literature used in the current study: the PRIME PCK rubric (Gardner & Gess-Newsome, 2011) and the CDK survey, based on the published work of others (Huizinga, 2014; Krajcik et al., 2008; Reiser et al., 2003). Several SLPAI criteria were without a direct relationship to the PRIME PCK rubric and CDK survey, so an additional resource was used. Davis and Krajcik’s (2005) design heuristics for educative materials considers PCK for science topics, PCK for scientific inquiry, and SMK. This paper was also featured in one evening session of the TSP PD program during a discussion on design knowledge.

**Daily reflections**

A component of DBR is to understand how learners think and feel regarding an innovation, and correspondingly, this study aimed to capture the teachers’ perceptions of the activity structures and design supports of the TSP PD and how they afforded or constrained their design expertise. Daily reflections were used to understand this construct (see Appendix J) as well as to understand if participants felt there were any changes to their learning, pedagogical practices, or instructional design decisions which correspond to self-reported changes in professional knowledge. Based on the 2015 TSP PD pilot and the structure of the Summer Research Experience, the daily program evaluation was modified and presented as daily reflections.

Participants were provided open-ended prompts and Likert-scale items each day in order to facilitate reflection and allow them to share their perceptions of the activity
structures and design supports of the TSP PD program and how they impacted their design expertise through the development of their curricular materials. Qualtrics was used to design and administer the daily reflections and the daily link was provided on the program website and sent electronically via email each day. For each day, the activities were presented along with a Likert scale so participants could provide a quantitative evaluation of their perceptions of each PD institute component and provide a self-evaluation of their level of engagement with the activity structures and design supports. An open response field allowed participants to provide feedback specific to each activity to elaborate how they perceived the impact of each activity on their design expertise. The program lasted 14 weekdays, and reflective journals were completed for the first 12 days of the program. Due to the interviews during the last week and the use of the storyline method on the final day, participants were not required to complete journal entries on days 13 and 14.

**Storyline method**

Since participants’ perceptions, or how they think and feel about an activity, may vary over the course of the TSP PD program, the storyline method was used as a summative instrument to measure participants’ perceptions and provide triangulation (see Appendix K). To capture participants’ reflections on the activity structures and design supports of the TSP PD, the storyline method was used (Beijaard, Van Driel, & Verloop, 1999). This method offers participants the opportunity to reflect on the entire three-week Summer Research Experience. Using the storyline method, participants were asked to draw a line on a chart which reflected their personal experiences with the activity structures and design supports of the TSP PD using the guiding question “How did you value the activity structures and design supports in the Summer Research
Experience?” Modeled after Huizinga (2014), participants were provided the activities with brief descriptions (e.g., ‘group materials development session reviewing exemplar curricula’) in chronological order to support their reflection. Participants drew their line in a coordinate system (x-axis activity structure, y-axis participant’s value of the process, 1 = very negative, 5 = very positive). After drawing the line, participants provided a written explanation to clarify their value of each activity.

**Semi-structured interview**

An additional element of the participants’ perceptions regarding the program is understanding how they approach design and their reasons for the instructional episodes they develop during the TSP PD program. Interviews provide a direct method for gaining rich descriptive data from each participant and allow probing to clarify ideas. Since the outcome of the program is a designed curriculum that translates each participant’s research experience into a classroom learning episode, I hoped to gain information about what elements of the TSP PD program they perceive as affording or constraining their design expertise by interviewing each participant. The questions are identified for the semi-structured interviews in Appendix L, however the order of questions and follow-up probing was determined during the co-construction of the interview with each participant as I looked for connections between the designed lessons and the TSP PD program in the teachers’ content knowledge, pedagogical content knowledge, and curriculum design knowledge as well as motivation and support for design expertise. This intention is similar to that of Schneider & Krajcik (2002) in their work to understand teachers’ use of educative materials in their classroom practices during a 10-week force and motion instructional unit. Interviews took place during the last week of the program when the teachers were focused on completing
their designed curricula. Each interview lasted between 30-60 minutes and was recorded and transcribed. Additionally, notes were taken during the interview and a summary written immediately following to record general observations and emergent themes from each participant.

Field notes

The designed learning environment and the multiple factors that contribute to the context are an important construct to consider in design-based research. One technique to record the complex interactions of the designed environment and the learners is for a participant observer to record field notes. I was a participant observer in this study as I not only participated in the events and resulting phenomena, I designed the learning environment. Field notes were kept throughout the TSP PD program to record descriptive and reflective information. Field notes were structured to include the elements of each activity structure and design support (date, time, location, who was present), descriptive elements (physical space, activities and behavior), descriptions of interactions between CPET staff, scientists, and teachers, and any informal interviews. These were followed by my reflections and interpretation of the TSP PD activities, however my reflections and interpretations were separate from the objective observations. To provide consistency in evaluating the level of engagement of each teacher with the activity structures and design supports and to compare to their self-evaluation, the daily evaluation completed by the participants was to be mirrored in the field notes to include an observational record of each participant’s engagement with the program activities and design supports (Appendix M). However, this became very cumbersome and time consuming, so observational records were condensed to one entry using the daily Qualtrics link.
Participant observation offers the advantages of providing a thick description of the designed learning environment in a design-based research study by describing activities in real time, recording the context of the case, and offering insights regarding interactions between participants. However, participant observation can generate selective data collection and be biased due not only to participant-observer’s interpretation but also due to her manipulation of events in the field (Yin, 2013). The use of multiple data sources (i.e., daily reflections, storyline, and interview data), additional observers (i.e., CPET staff, former intern), and member-checking techniques, were used to provide additional perspectives to triangulate and validate the views of the researcher to minimize bias.

**Data Analysis**

The first research question addresses the design conjecture: How do the activity structures and design supports of the TSP PD influence subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge? To answer this question, subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge were measured with quantitative instruments. Individual, average, and normalized gain scores were computed to better understand if there was a change in knowledge and the magnitude of any change. Non-parametric measures were also used to test for statistical significance. Since the assumption of normality was violated, related-samples Wilcoxon Signed Rank tests were used to compare the means of the pre and post as well as the retrospective and post administrations of the CDK survey to determine if there was a significant change in the participant’s curriculum design knowledge that can be attributed to the TSP PD program. As an additional measure of participants’ changes in professional knowledge, the reflective journals were utilized.
For each of the first 12 days of the program, participants were asked to use a Likert-type response scale to indicate the extent an activity structure or design support (i.e., laboratory, evening session, curriculum development) impacted their learning, pedagogical practices, and instructional design decisions, as well as their engagement with the activity. Means for each day were computed and compared. Supporting comments were analyzed using content analysis to identify how the participants believed the activities impacted their professional knowledge.

The second and third research questions address the theoretical conjecture: How do changes in subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge relate to the development of design expertise? and How do participants perceive the activity structures and design supports of a teacher-scientist partnership professional development program affording or constraining their design expertise? To answer the second question, the subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge (i.e., objective measures of professional knowledge) gain scores were used as well as a measure of design expertise (Hake, 1998). The normalized gain scores from the SMK, PCK, and CDK instruments used to answer research question one were used in conjunction with the normalized SLPAI gain score to determine if there was a relationship between professional knowledge and design expertise.

To answer research question three, a storyline approach and semi-structured interviews were employed to understand the perceptions of the participants as to what features of the TSP PD were most valued in their development of curricular materials. Storylines produced by the participants along with transcribed interviews were analyzed
using the constant comparative method (Creswell, 2014; Erickson, 2012). Primarily
deductive coding based on the activity structures and design supports was used during
initial coding, however some additional inductive codes emerged. Initial codes were
combined into conceptual codes that were then grouped during axial coding to allow
themes to emerge from the data. Emerging themes were identified to characterize the
perspectives of the participants as to what features of the TSP PD were most valued in
their development of curricular materials. These themes were triangulated with other
data sources (i.e., reflective journals, storyline, interview, and field notes), providing
validity for the findings.

**Trustworthiness**

Efforts must be taken to ensure the accuracy of the findings of the case study in
this project. As this is a naturalistic study, the burden of reliability falls on the
interpretations of the qualitative data. I use both quantitative and qualitative terms below
to address the diversity of instruments and methods of this study and the overlapping
nature of similar constructs to address the techniques and methods used to assure
trustworthiness.

**Credibility or Construct Validity**

Credibility or construct validity is concerned with identifying sound procedures to
investigate the constructs of the study (Creswell, 2014; Yin, 2013). It can also be
thought of as the degree to which an instrument measures what it is intended to or the
degree that the conclusions accurately reflect the construct. For the qualitative data,
credibility is established by gathering evidence from multiple instruments to triangulate
the data sources. Depending on only one source of evidence could lead to incomplete
conclusions but having multiple sources of evidence that converge (or triangulate) with the same or similar conclusions lends credibility to the findings.

Member checking was used to check my notes and perceptions against that of the participants as well as the other center staff. I did this in an ongoing process during data collection as field notes and summaries are made as well as once the data were analyzed and reported. I did this not only to maintain credibility in the study, but also to maintain a relationship of respect and trust with the participants.

For the constructs measured with quantitative instruments, the following steps are taken to ensure construct validity:

- Subject matter knowledge: The biomedical knowledge assessment was developed specifically for this study using assessment items from published sources, assessed for face validity by science education researchers, assessed for content validity by a biomedical science researcher, and pilot tested to determine usability and reliability;

- Pedagogical content knowledge: The PRIME PCK Rubric was previously found to be valid and reliable;

- Curriculum design knowledge: This instrument was developed specifically for this study based on design principles found in the literature and pilot tested to determine usability and reliability;

- Design expertise: The SLPAI was previously found to be valid and reliable.

**Generalizability or External Validity**

Using a case study approach within the design-based research paradigm supports the idea of transferability or generalizability in so much as rich descriptions of the designed learning environment allow others to decide how transferable the findings are to their own particular situation. DBR depends on thick descriptive datasets to help others understand the multiple interacting factors between the teachers, environment, and resources and the multiple decisions made by the designer, researchers, and
teachers in the designed learning environment. Only through detailed descriptions of the innovation can others determine generalizability.

Due to the small, convenience sample drawn for the constructs measured with quantitative instruments, this study does not claim external validity.

**Dependability or Reliability**

Yin (2013) states that the goal of reliability is to minimize the errors and biases in a study and to make it possible for another researcher to follow the same procedures and come to the same conclusions. To do this, an audit trail is necessary ensuring methods and analyses are thoroughly documented, transparent, and understandable. The audit trail for this study consists of the study proposal, accomplished through this dissertation, and maintaining all data and analysis in an electronic database. Field notes also serve as a researcher’s log to record events of the study as they occur.

**Benefits and Limitations**

The main limitations of this study are related to the small sample size and unique context. The small sample size limits the statistical significance of quantitative measures and reduces the generalizability or transferability of the findings. The length of the program introduces many contextually-related decisions that may not be applicable to other settings (DBRC, 2003). Additionally, the study participants applied and were selected to attend the TSP PD program that is the subject of this study, so they are likely not representative of all teachers.

This study provides empirical evidence of which activity structures and design supports present in a TSP PD program are valuable to the participants and how they leverage those elements to develop or deepen their subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge as they design
learning experiences appropriate for their particular classroom context. Unique to this study was the opportunity to work with a cohort of high school science teachers during the on-campus portion of the TSP PD as they design lessons for their classroom. This study was situated in an established TSP PD program and builds on previous evaluation of the program and previous work with a similar program investigating the affordances and constraints of teachers as curriculum adaptors (Brown et al., 2014). The TSP PD program in this study is funded by a Science Education Partnership Award from the National Institutes of Health to CPET through Spring 2017.

Statement of Subjectivity

Within the design-based research paradigm, the researcher is often the designer of the learning environment, as I am in this study. As such, I am an advocate and critic of the current iteration (DBRC, 2003). I have a vested interest in the current TSP PD program succeeding as measured by the completion of educative materials designed by the teachers translating their research experience into learning experiences for their students.

I am a member of the program staff and as such bring potential bias to the study. For example, drawing from previous experience, I will work with the program coordinator to assist teachers in anticipating and purposefully designing for their particular context, particularly mindful of pacing guides and standardized testing constraints. I will design and implement the intervention that is the subject of this study. I also fill the role of a facilitator experienced in both the world of university science content and laboratory research experience and K-12 science education. Previous work has shown this role to enhance the TSP, providing the middle ground between the two worlds and helping facilitate a productive and mutual learning relationship (Houseal et
al., 2014; Moreno, 1999; Moreno, 2005; Tanner et al., 2003). Bokor and Crippen (2016) also identified participants develop a trusting relationship with this role that fosters positive attitudes about TSP PD participation.

My relationship with the study participants is both a strength and limitation of this study. I oversee all CPET PD programs and take part in the selection process for each, including the TSP PD program that is the subject of this study. I spend a considerable amount of time with each of them professionally during scheduled programmatic activities as well as casually during informal gatherings. Rather than try to minimize the potential impact my personal relationship could play in the analysis, I take a strong objectivity stance (Harding, 1993), adopting a standpoint epistemology, acknowledging that I cannot remove myself from the context since I contributed to the creation of the professional development experience these individuals have while on the University campus by orchestrating the environment they were situated in for three weeks. I am not objective in the analysis of the experiences and my familiarity with the participants amplifies the voice I am able to give to each. Hill and colleagues (2013) describe “positive effects may also result from characteristics of the original group of teachers, characteristics of the facilitators, or the interaction of the two. These facilitators are often the developers of the program, which may additionally positively bias results” (p. 479).
Figure 3-1. High level, design, and theoretical conjectures.
Figure 3-2. Embodiments, mediating processes, and outcomes.
Table 3-1. Activity structures and design supports of the Summer Research Experience teacher-scientist partnership professional development program.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Summer Research Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity structures</strong></td>
<td>Support for subject matter learning and learning about student conceptions (Garet et al., 2001; Silverstein et al., 2009)</td>
</tr>
<tr>
<td></td>
<td>Content from scientists</td>
</tr>
<tr>
<td></td>
<td>Explicit reflection on student conceptions of biomedical science topics during group session and design tasks</td>
</tr>
<tr>
<td></td>
<td>Use of active learning strategies (Brown et al., 2014; Voogt et al., 2011)</td>
</tr>
<tr>
<td></td>
<td>1st person experience with activities</td>
</tr>
<tr>
<td></td>
<td>Group discussions</td>
</tr>
<tr>
<td></td>
<td>Creating an multi-lesson unit</td>
</tr>
<tr>
<td></td>
<td>Collective participation (Bokor &amp; Crippen, 2016; Dresner &amp; Worley, 2006; Van de Berg, 2002)</td>
</tr>
<tr>
<td></td>
<td>Teachers share teaching practices</td>
</tr>
<tr>
<td></td>
<td>Teachers participate in discussions of curriculum development in whole and self-selected groups</td>
</tr>
<tr>
<td></td>
<td>Duration and time span (Cohen &amp; Hill, 2001; Dresner &amp; Worley, 2006; Supovitz &amp; Turner, 2000)</td>
</tr>
<tr>
<td></td>
<td>3-week summer program</td>
</tr>
<tr>
<td></td>
<td>Informal, electronic follow-up throughout the year</td>
</tr>
<tr>
<td></td>
<td>Classroom visit with implementation assistance if requested</td>
</tr>
<tr>
<td></td>
<td>Interim implementation report and presentation Jan/Feb 2017</td>
</tr>
<tr>
<td></td>
<td>Coherence with teachers’, schools’, and districts’ goals for teacher learning (Penuel et al., 2007; Rivet, 2006)</td>
</tr>
<tr>
<td></td>
<td>Program supports teachers in designing units aligned with district/state goals</td>
</tr>
<tr>
<td></td>
<td>Exemplar materials aligned with state and national standards and district pacing guide (may not be explicitly presented)</td>
</tr>
<tr>
<td></td>
<td>Curriculum template is provided</td>
</tr>
<tr>
<td></td>
<td>Design supports</td>
</tr>
<tr>
<td></td>
<td>Structured activity development time (independent and group)</td>
</tr>
<tr>
<td></td>
<td>Use of assessments and data-driven evaluation of activities explicit through curriculum development</td>
</tr>
<tr>
<td></td>
<td>Feedback from program coordinators</td>
</tr>
<tr>
<td></td>
<td>Models and materials available for lesson design (Huizinga, 2014; Huizinga et al., 2015; Penuel et al., 2011)</td>
</tr>
<tr>
<td></td>
<td>Teacher-found and teacher-made lessons (self or peers)</td>
</tr>
<tr>
<td></td>
<td>Textbooks</td>
</tr>
<tr>
<td></td>
<td>Exemplar curriculum materials and resources</td>
</tr>
<tr>
<td></td>
<td>Degree of explicitness in teaching a design model of instruction (Penuel et al., 2011)</td>
</tr>
<tr>
<td></td>
<td>Aspects of Understanding by Design will be used</td>
</tr>
<tr>
<td></td>
<td>Inclusion of the ADDIE model as primer to design</td>
</tr>
<tr>
<td></td>
<td>Designing learning-goals driven educative materials</td>
</tr>
<tr>
<td></td>
<td>Heuristics for developing educative curricular materials</td>
</tr>
</tbody>
</table>
Table 3-2. Participant profile of 2016 Summer Research Experience TSP PD program.

<table>
<thead>
<tr>
<th>Demographic variable</th>
<th>Variables</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Female</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>1</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>Asian or Pacific Islander</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Black, non-Hispanic</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Hispanic</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>White, non-Hispanic</td>
<td>8</td>
</tr>
<tr>
<td>Highest earned degree</td>
<td>Bachelor's</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Master's</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Specialist</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Doctorate (PhD and EdD)</td>
<td>3</td>
</tr>
<tr>
<td>Bachelor's degree major</td>
<td>Biology</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Other life science (Nursing, Medical Technology, Natural Resources)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Chemistry</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Science education</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Education</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Other (Computer Science, Geology)</td>
<td>2</td>
</tr>
<tr>
<td>Teaching experience (years)</td>
<td>0 to 5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>6 to 10</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>11 to 15</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>16 to 20</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>&gt;20</td>
<td>2</td>
</tr>
<tr>
<td>School type (2015/16)</td>
<td>Middle school</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>High school</td>
<td>11</td>
</tr>
<tr>
<td>Previous Center programs</td>
<td>ICORE</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Bench</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Both</td>
<td>4</td>
</tr>
</tbody>
</table>
Table 3-3. Research questions, constructs, associated instruments, and data sources.

<table>
<thead>
<tr>
<th>RQ 1</th>
<th>RQ2</th>
<th>RQ3</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do the activity structures and design supports of the TSP PD influence subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge?</td>
<td>How do changes in subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge relate to the development of design expertise?</td>
<td>How do participants perceive the activity structures and design supports of a teacher-scientist partnership professional development program affording or constraining their design expertise?</td>
</tr>
</tbody>
</table>

| Subject matter knowledge, Biomedical knowledge assessment | X | X |
| Pedagogical content knowledge, PCK PRIME rubric | X | X |
| Curriculum design knowledge, CDK Survey | X | X |
| Design expertise, SLPAI | X |
| Perceptions, Daily reflections | X |
| Perceptions, Storyline method | X |
| Perceptions, Interview | X |
| Context, Field notes | X |
CHAPTER 4
FINDINGS

This chapter presents the findings for each of the research questions. Question one considers the influence of the TSP PD program on teacher professional knowledge, specifically subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge. The second question focuses on design expertise and how the three types of professional knowledge might be related to the development of design expertise. The third and final question considers the participants’ perspectives about how the activity structures and design supports afforded or constrained the development of their design expertise.

**Findings for Research Question One: Influence of the TSP PD Program on Teacher Professional Knowledge**

Research question one considers how the activity structures and design supports of the TSP PD influence subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge. Instruments were used pre and post program to produce a quantitative measure of changes in professional knowledge that could be attributed to the TSP PD. Each form of professional knowledge (subject matter knowledge, SMK; pedagogical content knowledge, PCK; curriculum design knowledge, CDK) is addressed below.

**Subject Matter Knowledge**

Subject matter knowledge was assessed using the Biomedical Knowledge Assessment (BKA) administered in paper format at the beginning (day one) and end (day 13) of the program. Participants were not time limited and all participants finished within 1hr and 40min. The assessment was comprised of two parts: 18 multiple-choice items and one free response question (FRQ) (Appendix C). The multiple choice items
were selected from established test banks (i.e., Campbell & Reece, *Biology* and AAAS) and scored one point each according to the published answers. The FRQ was previously administered by the College Board as an Advanced Placement (AP) Biology test item (2010, Form B, Question 2) earning a maximum of 12 points according to the published scoring guidelines. An experienced AP Biology teacher and myself scored the pre-program administration of the BKA FRQ independently using the published scoring guidelines. Since the sample size was low, each participant's final score was reached by discussing to consensus and repeatedly comparing responses and scores between participants to ensure consistency in scoring and alignment to the published scoring guidelines.

At the end of the program, participants were given their original responses to reconsider and modify directly on their original response or use a blank answer booklet to compose a new response. Participants were not made aware of their previous scores. Few participants made any changes to their original responses. Since so few changes were made, I was able to consider only those changes in comparison to their original response to determine if any additional points were earned on the FRQ. SMK scores are presented in Table 4-1. There was little change in overall SMK for the 11 participants (Pretest: \( M = 16.27, SD = 5.31 \); Posttest: \( M = 17.45, SD = 4.23 \)), and the participants performed better on the multiple-choice items (Pretest: \( M = 12.09, SD = 2.91 \); Posttest: \( M = 12.63, SD = 2.20; \sim 67\% \) correct) than the FRQ (Pretest: \( M = 4.18, SD = 2.72 \); Posttest: \( M = 4.82, SD = 2.32; \sim 35\% \) correct). Based on the Wilcoxon Signed Rank test, there was no significant difference in the pre and post assessment means (\( T = 24, p = 0.088 \)).
For some participants, their answers on the FRQ were brief and did not address the key items and associated points the scoring guide indicated. The participants were not made aware the FRQ was an AP Biology item and would be scored using the scoring guidelines from College Board as this might have given an advantage to those teaching AP Biology and more familiar with the scoring procedures. When using the scoring guidelines, we found items that were awarded points, but we did not feel were well aligned with the FRQ. For example, simply including the phrase “heterozygote advantage” earned a point, although respondents were free to use any disease example to demonstrate the persistence of mutant alleles in a population. This seemed to favor those learners who had been specifically taught or themselves teach using sickle cell disease as an example and underscores the specific curriculum of the AP Biology course rather than depth and application of knowledge. Another participant scored very poorly (0pts) as she based her brief answers on plant genetics and incorrectly detailing polyploidy events which did not address an understanding of human genetics and disease as the FRQ asked and the scoring guidelines described.

**Pedagogical Content Knowledge**

As a measure of pedagogical content knowledge (PCK), participants were asked to describe the student and teacher activities they would use in an instructional episode on protein synthesis. Participants were also prompted to respond to nine questions to elaborate their rationale for their instructional practices described in the student and teacher activities. Participants were sent this reflective prompt prior to the program and encouraged to use resources from their classroom. Participants were asked not to perform additional research and look for ways to teach protein synthesis but rather depend on their current knowledge and instructional practice to answer as completely
as possible. The prompt was modeled after the PRIME PCK reflective prompt by Gardner and Gess-Newsome (2011) and the associated published PRIME PCK rubric was used as described to score the submissions collected at the start of the TSP PD program.

The same experienced AP Biology teacher who scored the FRQ and myself scored the pre-program administration of the PCK prompt independently using the published rubric. Since the sample size was low, each participant’s final score was reached by discussing to consensus and repeatedly comparing responses and scores between participants to ensure consistency in scoring and alignment to the published rubric.

Following the same procedure used for the BKA, participants were given their original PCK responses at the end of the program to reconsider and modify directly on their original response or use a blank answer booklet to compose a new response. Participants were not made aware of their previous scores. Few participants made any changes to their original responses. Since so few changes were made, I was able to consider only those changes in comparison to their original response to determine if any additional points were earned. There was little change in overall PCK for the 11 teachers (Pretest: $M = 10.55, SD = 3.01$; Posttest: $M = 10.91, SD = 3.21$) after the three-week TSP PD program and no significance in the differences ($T = 6, p = 0.102$). PCK scores are presented in Table 4-2.

The PRIME PCK rubric addresses three elements of PCK: content knowledge (PCK-CK), pedagogical knowledge (PCK-PK), and contextual knowledge (PCK-CxK), with the latter two elements collapsing into one factor named PCK-pedagogical
knowledge (PCK-PK). The participants showed greater means on PCK-CK (Pretest: $M = 5.91$, $SD = 1.97$; Posttest: $M = 6.18$, $SD = 2.09$) compared to PCK-PK (Pretest: $M = 4.64$, $SD = 2.11$; Posttest: $M = 4.73$, $SD = 2.10$). The participants did not include enough detail to accurately portray the learning episode, and the brevity of the responses from the study participants resulted in few scores of proficient (2pts) or advanced (3pts) teacher knowledge.

**Curriculum Design Knowledge**

Self-assessment of CDK is positively influenced by participation in the TSP PD program ([Table 4-3](#)). The CDK survey ([Appendix F](#)) was based upon a literature review of design principles and practices, specifically those used by classroom teachers directly or intended to be used in collaboration with teacher partners. Items were adapted from Hardre’s (2003) instructional design knowledge and strategies, Huizinga’s (2014) features of curriculum design expertise, and Reiser, Krajcik, and colleagues’ (2003, 2008) design strategies for developing science instructional materials. All of these design practices have a foundation in the principles of the ADDIE model of instructional design.

As the participants were experienced classroom teachers who had previously participated in a two-week TSP PD program, it was hypothesized the participants might have a strong positive perception of their personal design knowledge prior to the program. The survey was administered as a repeated measure at the start of the program and then again at the conclusion of the program as a retrospective and post survey. The survey presented 15 design elements and the participants were asked to indicate the degree of agreement that they performed each of the design practices. The survey of CDK indicated strong agreement of usage of curriculum design practices.
before the TSP PD program based on a mean score of 78.27 points ($SD= 6.28$) out of a maximum 90 points (see Table 4-3). When participants considered their incoming CDK retrospectively, the mean was slightly lower ($M = 73.81$, $SD = 9.21$) than they had initially indicated. Importantly, the participants felt their CDK had increased after participation in the TSP PD ($M = 84.64$, $SD = 6.09$) compared to both their pre-program and retrospective scores. Wilcoxon Signed Rank tests of related samples were performed to determine if the change between pre and post administration and retrospective and post administration was significant (Table 4-4). For both pairings, the means were significantly different (Pre:Post $T = 52$, $p = 0.012$; Retro:Post $T = 45$, $p = 0.008$) and the effect was large (Pre:Post $r = 0.533$; Retro:Post $r = 0.569$) based on Cohen’s description of a large effect (Cohen, 1988).

Considering average gain between the pre and post administrations as well as the retrospective and post administrations, the overall normalized gain scores (pre:post $<g> = 0.542$, retro:post $<g> = 0.669$) indicate medium to high gains (Hake, 1998) where high gain is ($<g> \geq 0.7$), medium gain is $0.7 > ( <g> \geq 0.3$), and low gain is ($<g> < 0.3$). For each, the highest gain score of 1 would indicate all possible points were achieved by all participants resulting in an average score of 6 and that all participants strongly agreed they utilized the design practice.

Looking closer at the individual design elements on the CDK survey, participants had a higher level of agreement about the extent they performed 13 of the 15 design elements before the program than they did retrospectively (Table 4-5). Two design elements scored lower on the pre administration than the retrospective: 1) Analyze state standards to identify each concept addressed within (Pre: $M = 5.27$, $SD = 0.65$; Retro: 
2) Create learning objectives that address each concept within the standards (Pre: $M = 5.18$, $SD = 0.75$; Retro: $M = 5.27$, $SD = 0.65$). This suggests participants felt strong agreement about their ability to perform these design tasks and the TSP PD program reinforced their prior conceptions of their level of agreement.

The participants’ level of agreement was greater on the post administration than on the pre or retrospective administrations for all 15 design elements (Figure 4-1). The two design elements that increased the most from the pre to post administrations were 1) Apply a logical, orderly method of identifying, developing and evaluating a set of planned strategies targeted for attaining the curricular goals (Pre: $M = 4.82$, $SD = 0.60$; Post: $M = 5.64$, $SD = 0.67$) and 2) Clarify the instructional problems and objectives and identify the learners’ existing knowledge and skills before developing or adapting learning activities (Pre: $M = 4.73$, $SD = 0.47$; Post: $M = 5.45$, $SD = 0.69$). Before the TSP PD program, participants felt less confident that they approached classroom instructional design in a systematic manner with attention to considering instructional objectives and activities with their students’ previous knowledge in mind than they did at the conclusion of the program.

Comparing the pre administration with the post administration, the normalized gain scores for each design element varied (Table 4-6). Again using Hake’s (1998) description of low, medium, and high gains, four design elements show low gains: 1) Develop goals, objectives, and pacing for curricular units; 2) Create and assemble learning materials for a curricular unit based on the design plan; 3) Engage in summative evaluation of a curricular unit in order to assess student learning outcomes;
and 4) Generate ideas about how to make improvements to a curricular unit. Two design elements show high normalized gains pre:post administration: 1) Analyze state standards to identify each concept addressed within and 2) Create learning objectives which address each concept within the standards. These two design elements were also described above as the only items to decrease in agreement from pre administration to retrospective. The remaining nine design elements show medium gains. However, when retro and post administrations are compared, greater gains are observed: four design elements show high gains while the remaining 11 show medium gains, and none of the elements show low gains.

**Evidence of Professional Knowledge in Reflective Journals**

To better understand if the TSP PD program influenced SMK, PCK, and CDK not detected by the BKA, PCK prompt, or CDK survey, an analysis of the reflective journals was conducted. At the conclusion of each day of the TSP PD program, participants were asked to reflect on changes to their learning, pedagogical practices, and design decisions as a result of the day’s activities and to indicate the amount of change using a Likert-type response scale and to provide comments to explain their score. It is these three items from 12 days of reflective journaling described in Table 4-7 that are utilized to examine changes participants identify in their own professional knowledge. Daily means for each item (learning, pedagogical practices, instructional design decisions) along with overall engagement with the activity (i.e., laboratory, evening session, curriculum development) are presented in Table 4-8.

Based on the daily means which are all greater than three (neutral), the participants perceived that the TSP PD activities were successful in influencing their learning, pedagogical practices, and instructional design decisions. The participants
were also somewhat to very engaged with each activity they were asked about on the daily reflective journal (laboratory, evening session, curriculum development), illustrating an overall positive experience with the activity structures of the TSP PD program. Although the quantitative instruments do not show a gain in SMK or PCK, the participants believe the TSP PD program has influenced their professional knowledge.

**Personal learning**

The mean learning score \((M = 3.88, SD = 0.24)\) provides evidence that the participants believe the TSP PD program has influenced their learning. When asked to describe what they did in their laboratory each day, the participants explained in great detail their experiences, exhibiting both enthusiasm and learning gains in content knowledge as well as laboratory skills. For example, Participant 8 exclaimed, “I enucleated cells!” (P8, Reflective journal, Day 5) while Participant 7 gave a detailed account of protein extraction and running a SDS-PAGE in preparation for protein fingerprinting via MALDI-TOF analysis (P7, Reflective journal, Day 8). Similarly, Participant 2 recounted his preparation of a *Salmonella* culture in preparation for whole-genome sequencing using the Illumina system.

We began the day with samples of salmonella ready to be sequenced by the Illumina equipment. We also had our partially prepared personal bacteria samples. We placed the salmonella samples in the sequencing machine anticipating partial readout by the end of the day. Next we continued processing our bacteria samples by washing and using enzymes that ultimately would purify our DNA and produce a sample appropriate for the sequencing process. …Also today we prepared another batch of salmonella samples for sequencing. The preparation of these samples will be completed tomorrow. The day was concluded with examination and analysis of the first stage of Illumina data output. [The graduate student] explained the significance of the general findings and showed us samples of other runs. (P2, Reflective journal, Day 3)
Participant 1 shared a procedure for cell culturing and inducing differentiation in the cell lines. Additionally, she references a new procedure used to examine epigenetic factors such as methylation and CpG islands. Participant 1 also reveals that she observed other activities in the research laboratory such as a high school student performing a restriction digestion.

Today my lab partner and I conducted the second step of our experiment which was a repeat of the procedure we watched our lab instructor perform yesterday. My lab partner performed the first half of the procedure (taking a sample of MEL cells, staining and counting them) while I performed the second half of the procedure (adding more culture medium - Eagle's medium, fetal bovine serum, penicillin/streptomycin - and add 2% DMSO to induce differentiation of the cell culture). I had to use a variety of tools that I had not used before under sterile conditions. Tomorrow we will be prepared to begin our MAPit procedure to find sequencing results. We also watched the experiment and procedures followed by the SSTP student today because he was testing 3 restriction enzymes on a DNA sample using gel electrophoresis. (P1, Reflective journal, Day 3)

The participants also reflected on their learning during their time spent in the laboratory and often shared appreciation for the numerous people they interacted with during their placement as well as the additional homework they felt they needed to understand the complexity and detail of the laboratory's research.

I appreciate the amount of knowledge I am gaining during my placement in [P1's] lab on the science of epigenetics. I had a noticeable gap in my understanding of epigenetics and have not spent enough time in planning or implementing a unit in my honors genetics course. The explanations provided during the lab rotation, the reading provided by my host lab, and the reading I have done on my own has truly expanded my understanding of epigenetics. (P8, Reflective journal, Day 11)

The participants shared very specific topics and procedures regarding their laboratory experience related to their personal learning. The comments also show that the content topic and related laboratory skills are unique to each participant or participant pair dependent on their laboratory placement.
Pedagogical practices

Participants placed a great deal of importance on their learning of new content and skills, often commenting about their laboratory activities and recounting new concepts they had learned and techniques they had performed. Often tied to their deepening subject matter knowledge were references to their pedagogical practices. The mean pedagogical practices score ($M = 3.75$, $SD = 0.39$) illustrates that placement in a research laboratory influenced not only the participants learning of new content and skills, but it also impacted their beliefs about their pedagogical practices such as integrating concepts in a meaningful fashion for their students.

They are doing some very complicated stuff and I just hope I can keep up. Very interesting. Completely unknown topic. I am basically learning about a disease caused by a trinucleotide repeat that affects alternative RNA splicing. These are all topics I address separately. This gives me a context to put it in. (P6, Reflective journal, Day 1)

My current unit of instruction using the concepts of transcription and translation is very weak. It has bothered me for some time, but due to lack of time during the school year, I had not been able to put in the effort needed to change the unit. I hope to completely change my pedagogical practice as a result of my lab experience here at UF. (P1, Reflective journal, Day 2)

I have a better understanding of how science really works (money, funding, lack of funding for, publication of "sexy" science, replication studies, etc) that I think could lead to some good discussions with students who are interested in science careers. I think I need to do a better job of teaching NOS within the context of ethics and emphasize the importance of peer review and replication. (P0, Reflective journal, Day 3)

Participants were critical of their current teaching and offered several changes they envisioned making including “My current pedagogical practice as it relates to transcription instruction lacks depth and example” (P1, Reflective journal, Day 3), “Have more discussion opportunities with my students” (P9, Reflective journal, Day 2 pm), “Importance of clarifying content and receiving student feedback to help understanding”
(P9, Reflective journal, Day 3), “Create a hook” (P10, Reflective journal, Day 2 pm), “More hands-on learning” (P11, Reflective journal, Day 2 pm), and “Incorporating more student-led/teacher facilitated components” (P3, Reflective journal, Day 10).

Participants also recognized the difficulty with adopting new teaching approaches, particularly when tasked with designing a new learning episode rather than adapting a lesson already available.

Subtle alterations in the focus of planning from teacher-delivery to student-centered. Getting ready to start on Lesson 3 tonight and still not sure where I want to go with it. It would be easy for me to fall back on my traditional lecture-style so I am struggling with how to deliver Lesson 3 - Tissue specific gene expression. (P8, Reflective journal, Day 11)

Changes in pedagogical practices were highest on the evening or day following an evening session, during which there was discussion among the participants regarding pedagogical approaches to various content areas. These sessions were structured for self-selected groups to work together and then share out for the group. Additionally, each participant was free to contribute additional thoughts aloud for whole group discussion. The participants indicated this collaborative sense-making time was effective and additionally contributed to their positive perspective of collective participation. There was an additional peak in pedagogical practices scores during the beginning of the last week as the participants concentrated on their designed curriculum and engaged in reflective thought as well as informal discussions with their peers (Figure 4-2).

**Instructional design decisions**

The participants’ instructional design decisions were positively impacted as a result of the TSP PD program ($M = 3.82, SD = 0.39$). The TSP PD program challenged the participants to translate their laboratory experience into a classroom module of three
to five lessons lasting approximately five 45-minute periods and to consider the design of their curricular module in a systematic, logical fashion. Readings and discussions related to design knowledge were the focus of the evening activities. Participants shared thoughts regarding changes to their instructional design.

I see a change in the progression of a lesson from a start to a finish. I was given a copy of UbD a few years ago from my district science C&I and have read it but obviously without the same focus I am reading it now. I found an appropriate statement in tonight's reading that may become my driving force..."how will we distinguish merely interesting learning from effective learning?" The study being done in my lab is interesting and can be an effective way to deliver content with a meaningful purpose. (P8, Reflective journal, Day 3)

I will change the way I teach genetics by using a project based learning approach in my biology and biotech classes. I can focus on SNP’s and genome sequencing at a higher level with appropriate exercises and activities to enhance the content and be able to assess their understanding. Hopefully it will stir some students into genetic research. (P9, Reflective journal, Day 3)

...the 9 elements outlined in the Appendix of the Davis and Krajcik article will be the driving force of my instructional unit as part of the SRE and, as much as possible, in all future lesson plans. (P8, Reflective journal, Day 2 pm)

Changes in instructional design decisions were highest for evening sessions as well as the beginning of the last week as the participants focused their efforts on their designed lessons (Figure 4-2). Over the duration of the three weeks, increases in pedagogical practices and instructional design decisions always occur concurrently suggesting the two constructs are related. Indeed, often the participant comments mix the two constructs. For example, one participant indicated the following as changes to her instructional design decisions: “Embed real world scenarios or projects, clarify misconceptions of students through peer to teacher discussions and have student apply knowledge with lab activity” (P9, Reflective journal, Day 3). This may suggest a specific
sequencing of activities which would be part of instructional design, however, the inclusion of specific pedagogical approaches may indicate misconceptions regarding the difference between the two constructs or it could suggest that instructional design and pedagogical practices are tightly interconnected for teachers as designers.

Engagement

Engagement was consistently the highest factor throughout the TSP PD program ($M = 4.46$, $SD = 0.30$). Participants scored high levels of engagement during all activities (laboratory, evening sessions, curriculum development) and through their comments share elements that maintained their engagement with the TSP PD program activities. Participants expressed excitement regarding their laboratory placements sharing that their lab was “Sooooo cool!” (P5, Reflective journal, Day 1) and “I love my placement. My brain is already full and I can’t wait to go back tomorrow” (P0, Reflective journal, Day 1). They also expressed overwhelming positive experiences with their fellow participants and laboratory researchers as well as evening sessions. Some participants shared their overall engagement with the TSP PD program, such as “I am growing and learning daily and feel very honored to be part of this enriching program! I always want to be a better teacher for the benefit of my students!” (P1, Reflective journal, Day 7) and “I am having a great time and learning so much. How I am going to organize that right now is a hot mess but I will figure it out” (P5, Reflective journal, Day 3).

However, all factors (learning, pedagogical practices, instructional design decisions, and engagement) decline in the last day of the reflective journals as the participants revealed their concerns about the final deadline and formatting requirements of compiling all of their materials into one document as well as the
cognitive load of translating their research experience into a newly designed curricular module. The participants shared their thoughts: “I feel very time crunched and my brain needs more time to process” (P6, Reflective journal, Day 11), “Time is beginning to run short. I want to create a quality product but I have to press on also. Having more time to work on the lesson might have been nice, but it is so easy to procrastinate when you have a sense of an abundance of time” (P2, Reflective journal, Day 11), and “My brain feels a bit fried at the end of the day. I don't think I have ever focused so intently on developing a lesson plan” (P8, Reflective journal, Day 11). These comments foreshadow the next research questions that consider how SMK, PCK, and CDK relate to design expertise and the affordances and constraints of the TSP PD program on developing design expertise.

The quantitative instruments used to measure SMK and PCK did not show learning gains, while the CDK survey showed medium to high gains from pre to post and retro to post. To better understand the participants’ perceptions of their learning and to determine if learning did occur that was not detected with the quantitative instruments, the participants’ daily reflective journals were analyzed. The participants’ perceptions of their learning, pedagogical practices, and instructional design decisions are positive as evidenced by scores of agreement and their associated comments. Additionally, participants report a high level of engagement with all activities. Taking the quantitative measures together with the reflective journal scores and comments indicates the TSP PD program activities structures and design supports did influence the participants’ subject matter knowledge, pedagogical content knowledge, and
curriculum design knowledge. How these might be related to design expertise is the focus of the next section.

**Findings for Research Question Two: How Professional Knowledge Relates to Design Expertise**

Research question two asks how changes in subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge relate to the development of design expertise. The Science Lesson Plan Analysis Instrument (SLPAI) was used to score each of the final designed curricula to determine a level of design expertise. To better understand how the design expertise score relates to SMK, PCK, and CDK, the original intention of this study was to utilize gain scores from these instruments. However, there were no gains in SMK and PCK so additional routes of inquiry were explored. An analysis of the professional knowledge types within the SLPAI categories considers how the participants scored in each knowledge type as differentiated in the SLPAI. Additionally, the reflective journal scores of learning, changes to pedagogical practices, and instructional design decisions and the participants’ supporting comments presented in the question one findings are considered in relation to the SLPAI scores of design expertise.

**Analysis of Design Expertise**

The measure of design expertise was based on a quantitative score utilizing the SLPAI rubric to assess level of mastery with 22 items on the participants’ designed curricular product (Jacobs et al., 2008). An experienced professional development provider familiar with the SLPAI and myself scored the designed curricular products independently using the published rubric. Since the sample size was very low, each
participant’s final score was reached by discussing to consensus and repeatedly comparing responses and scores between participants to ensure consistency in scoring.

The SLPAI rubric assigns three levels of points: 0pts = needs improvement, 1pt = making progress, and 2pts = exemplary for each of the 22 categories. Weights are associated with each category as well to allow flexibility as they relate to different PD programs. In this study, the original weights were used as described to maintain consistency between the published rubric and the use of the rubric by others, including myself (Brown et al., 2014; Jacobs et al., 2008). Total weighted scores were normalized to 100 as previously described (Brown et al., 2014; Jacobs et al., 2008). Normalized scores ranged from 52 to 100 and the distribution was positively skewed ($N = 11, M = 71.18, SD = 17.44$) indicating all participants were successful with the task of designing an instructional unit. The high mean for the cohort indicates they were highly successful using the success categories described by Brown and colleagues (2014). The individual SLPAI scores and associated success level are presented in Table 4-9.

The designed curricula all followed the template provided by the TSP PD program, however the content within varied widely. Brief summaries of each curriculum with sample strengths and weaknesses are presented in Appendix L. Some of these are highlighted below as well.

**Professional knowledge types within the SLPAI as related to design expertise**

The SLPAI criteria align predominately with PCK, followed distantly by CDK, PK, and SMK (Table 4-10). The majority of the SLPAI criteria (15 of 22) align with PCK (PCK-content knowledge and PCK-pedagogical knowledge). Only four of the 22 categories (Alignment with standards, Goal orientation, Meaningful application, Assessment) correlate to a measure of CDK, and only one category on the SLPAI
(Content accuracy) directly references SMK. Two categories (Preassessment and Meaningful application to students) are aligned with both PCK and CDK. Four categories (Awareness of science education research, Equity, Appropriate use of technology, Adaptability) do not correlate to SMK, PCK, or CDK based on the resources used in this study. These criteria are similar to items in the NSES Teaching Standards (NRC, 1999) and most closely align to pedagogical knowledge, which is not considered in this study.

To consider each of the categories individually and the associated professional knowledge, unweighted category scores are used to calculate the mean for each. For the majority of the categories (18 of 22) the mean was 1.00 or above, indicating progress was being made toward that component (see Table 4-8). The four items that did not reach this level (Preassessment, Student attitudes about science, Nature of Science, Error analysis) were all aligned with PCK items. Additionally, preassessment is dual-aligned with CDK based on the Understanding by Design model.

**Preassessment.** The designed curricula scored poorly in the preassessment category \((M = 0.45, SD = 0.52)\). Several curricula did not include any preassessment strategies, and those that did, often did not include how the results would be used to alter instruction, resulting in a score of making progress (1pt). Common was the inclusion of a summative pretest/posttest that was intended to be used to evaluate the curriculum rather than understand student prior knowledge and modify instruction accordingly. Mention of bellringers and other quick preassessment techniques were included, but again, there was no indication of using the formative results.
**Student attitudes about science.** An exemplary score (2pts) in Student Attitudes about Science must demonstrate that changes in values and attitudes in science were directly assessed. None of the designed curricula achieved this score resulting in a low mean \((M = 0.73, SD = 0.47)\). Most curricula did not directly assess changes in values and attitudes in science, resulting in a lower score of making progress (1pt). This seemed an important category for the participants as many of them included comments related to making science fun and relevant for the students, but they did not explicitly address how they would measure changes in student attitudes.

**Nature of Science.** The designed curricula did not meet the criteria of the SLPAI rubric and resulted in low scores for the Nature of Science category \((M = 0.91, SD = 0.83)\). Nature of Science was problematic to score because it is strictly and narrowly defined in the SLPAI to include two key elements: “Explicit mention of how theories are tentative and develop and change over time based on new evidence or new treatment of previous evidence” and “Science is treated as a social endeavor involving argumentation and explanation” to receive the score of exemplary (2pt). The making progress score (1pt) “Reflects an attempt to represent the nature of science” and needs improvement (0pts) stated, “Treats science exclusively as a body of factual knowledge to be committed to memory AND/OR Treats experimentation exclusively as a way to find the ‘truth’” (p. 1123). Only three of the designed curricula achieved a level of exemplary (2pts), four achieved a level of making progress (1pt), and four received no points. While it was easy to discern those curricula that needed improvement in the NOS criteria through their use of didactic approaches and complete lack of inquiry, others were scored as making progress (1pt) because there was not specific mention of
the tentative nature of theories or science as a social endeavor even though they consistently engaged students in the practices of science consistent with NOS literature.

**Error analysis.** Scores for error analysis were the lowest of all categories \((M = 0.27, SD = 0.65)\). Most designed curricula scored needs improvement (0pts) for the Error analysis criteria because they did not include any error analysis in their lessons. The SLPAI rubric specifically calls for inclusion of instruction on experimental error. This level of detail is not found in every learning episode and the rubric favored those who wrote lessons within their curricula that included appropriate activities to foster explicit instruction of error analysis.

Conversely, the designed curricula were scored near exemplary in two categories (Alignment with standards, Meaningful application) as described below.

**Alignment with standards.** The designed curricula scored very well on the CDK aligned criteria Alignment with Standards \((M = 1.91, SD = 0.30)\), consistent with the participants’ level of agreement on the CDK survey. Those that scored making progress (1pt) was primarily due to the incompleteness of the standards alignment such as including lessons that did not include any or all of the applicable standards. Some curricula also included standards that were not directly aligned with the lessons and did not correlate standards, objectives, and assessments.

**Meaningful application.** Designed curricula neared exemplary for criteria Meaningful Application \((M = 1.73, SD = 0.47)\), a dual PCK/CDK item. The curricula included topics and pedagogical approaches that engaged students in relevant and meaningful learning episodes, translating the research experience into a context the students could relate. For example, one participant framed her curriculum around
environmental toxins and used common household items as the toxicants that are used by her rural students, such as motor oil, pesticides, fertilizers, and soaps such as those used at school car washes.

For the remaining 16 categories, the mean unweighted score was between 1-2 with exemplary and needs improvement examples in each, but indicating that overall the designed curricula and therefore the measure of design expertise was making progress toward exemplary.

Professional knowledge types within the reflective journals as related to design expertise

As previously shown, the participants believed the TSP PD program was successful in influencing their learning, pedagogical practices, and instructional design decisions. Although the instruments used (BKA and PCK prompt) did not indicate changes in SMK or PCK, the participants’ comments provide evidence of elements that contributed to them being successful with the task of designing a product and demonstrating a positive level of design expertise. The supporting comments provided in the reflective journals include statements that indicate positive changes to their learning, pedagogical practices, and instructional design decisions. This indicates the TSP PD program did have an influence on their professional knowledge and the successful development of a designed curricular product can be attributed in part to the elements of the TSP PD.

Design expertise is the integration of subject matter knowledge, pedagogical design knowledge, and curriculum design knowledge and a term that is not common knowledge among teachers. In the reflective journal, participants were not asked directly how their design expertise was impacted, but they were asked to describe their
experience with designing curriculum. During the final week, the participants shared their thoughts to the following prompt on Day 10: “As you reflect on your curriculum design and writing process overall, what are your thoughts regarding your experience?”

Their comments indicate changes in SMK as they share increased content knowledge: “I am going to be much more knowledgeable about current biological research” (P1, Reflective journal, Day 10) and “I have learned a great deal of detail in the content area of my lesson and lab” (P6, Reflective journal, Day 10). PCK was also impacted as participants gained an appreciation for how their students learn and want to be taught: “I want to teach everything I experienced as a student” (P4, Reflective journal, Day 10) and “…high school students need to be exposed to these biomedical concepts and research ideas. This drives me” (P7, Reflective journal, Day 10).

Following an explicit design model and development of CDK as an ongoing process is challenging was also evident: “Wow!! This is a process” (P11, Reflective journal, Day 10) and “I've spent a great deal of time researching and writing lessons that will never see this particular curriculum. …On the other hand, I'm fairly sure that I will use the lessons at some point in the coming year so it is not time completely lost” (P3, Reflective journal, Day 10). The participant responses show that SMK, PCK, and CDK were impacted through designing a curricular module which results in a measurable level of design expertise.

All of the participants achieved a successful level of design expertise. Based on quantitative scores from the instruments intended to measure SMK, PCK, and CDK, only CDK changes as a result of participation in the TSP PD program. The reflective journals and the SLPAI criteria alignment indicate that SMK (learning), PCK
(pedagogical practices), and CDK (instructional design decisions) were largely positive. Something is facilitating the participants’ successful design expertise and taken together, it seems the largest contributor is CDK.

The reflective journal comments suggest another component regarding the development of design expertise beyond the three professional knowledge types considered in this study—the personal resources and design capacity of the individual. For example, “Writing a curriculum does not come easy for me” (P7, Reflective journal, Day 10) demonstrates the difficult process of curriculum design for some but “I will enjoy teaching this lesson because I developed it” (P10, Reflective journal, Day 10) and “I think that I will be a better teacher as a result of this experience” (P2, Reflective journal, Day 10) demonstrate the pride and sense of accomplishment gained from teachers taking on the role of designer and translating their research experience into a curriculum. Question three explores these ideas further by considering the participants’ perceptions of how the activity structures and design supports afforded or constrained their curriculum development.

**Findings for Research Question Three: Participant Perceptions of the TSP PD Program Activity Structures and Design Supports**

Research question three considers the participants’ perspectives by asking how participants perceive the activity structures and design supports of a teacher-scientist partnership professional development program affording or constraining their design expertise. The results from two primary data sources, the storyline reflection and individual semi-structured interviews, are presented below. First, the quantitative scores from the storyline reflection provide a general summary of the participants’ perspectives. Next the results of the qualitative analysis of the supporting comments for each of the
ten components listed on the storyline reflection and the semi-structured interviews are presented.

**Storyline Reflective Method**

The storyline reflection was administered on the last day of the program after the final presentations of the designed curricula and just prior to the participants departing campus. The storyline reflection presented the participants with a blank graph that asked them to consider “How did you value the activity structures and design supports in the Summer Research Experience?” Ten activity structures and design supports were listed, and the participants assigned a numerical score (1 = Very negative, 2 = Negative, 3 = Neutral, 4 = Positive, 5 = Very positive) by placing a dot on the graph and connecting their dots with a single line. Means were calculated for each of the ten components (Table 4-11). Participants were also asked to provide comments for each of the activity structures and design supports to explain the numerical score.

Each of the mean scores was 4.00 (Positive) and above, indicating the participants valued all the activity structures and design supports of the TSP PD program. Five components were perceived as Neutral (score of 3) to some participants (Laboratory experience, Evening design sessions, Interactions with former intern, Curriculum writing, and Individual curriculum design meetings with coordinator) but other participants scored these same components as Very positive (score of 5). Three items (Evening group sharing session, Informal Friday lunches, and Presentation of designed unit) were perceived by all participants to be Positive or Very positive (score of 4 or 5) components of the TSP PD program. Two items received unanimous scoring: Daily reflection (Positive, score of 4) and Informal conversations with peers (Very
positive, score of 5). Supporting comments for each component are considered next to reveal the variation in the participants’ perspectives.

The supporting comments offered for each of the ten TSP PD program components are quite brief, but they provide a starting point to better understand the variation of perspectives. Many of the comments were quite similar to each other and overall reflect and support the positive scores described above. Table 4-12 presents two example comments for each of the components which illustrate the consistency between the participants in their summative views.

**Laboratory experience**

The laboratory experience ($M = 4.30$, $SD = 0.82$) provided neutral value to those that did not have adequate “hands-on” (P6, Storyline) opportunities within the laboratory, but others felt it was the best “lab learning experience” (P7, Storyline). While the positive comments do not specifically mention the inclusion of “hands-on” it could be that those participants who had more opportunities to participate in laboratory experiments placed greater valued on their laboratory experience than those who only observed techniques.

**Evening design sessions**

Evening design sessions ($M = 4.00$, $SD = 0.67$) that focused on science education research surrounding designing educative materials and presented the participants with research articles for discussion were viewed with less value by participants who interpreted the curriculum design principles as being “theoretical” rather than “skills based” (P6, Storyline). Conversely, other participants valued the evening design sessions and indicated familiarity with some of the design principles stating it “was good to revisit the idea of backwards teaching” (P2, Storyline).
Interactions with former intern

A former intern was situated in the TSP PD program with the 11 participants to provide additional just-in-time support and collegiality and function as an additional program facilitator. Perceptions of the value of interactions with former intern ($M = 4.20, SD = 0.79$) varied between neutral because “she did not have any impact on my learning or lesson” (P6, Storyline) to very positive, citing the former intern’s previous experience writing curricula in the Summer Research Experience as a valuable opportunity for peer support. It is important to note however that the former intern was only able to be with the participants during the first two weeks of the program and was not on campus during the final week when the participants were focused most intently on their curriculum writing.

Curriculum writing

Curriculum writing ($M = 4.20, SD = 0.63$) was the primary activity structure of the final week of the program and again participants placed differing value on the experience from neutral to very positive. Their comments are fairly consistent citing the intensity and difficulty designing and writing a novel curriculum in a short summer program but that it was also a “great learning experience” (P7, Storyline) and “good skill developer for teachers” (P4, Storyline). For the one participant who scored a 3, it may be that while she recognized the value to her personal learning and professional practice, the discomfort of the process depressed her overall value of curriculum writing.

Individual curriculum design meetings with coordinators

Individual curriculum design meetings ($M = 4.60, SD = 0.70$) was the final activity structure that participants scored between 3 and 5. Feedback and conversations occurred between the participants and the program coordinators continuously.
throughout the program via email, comments on design assignments, and face-to-face sessions. All of the comments reflect a positive value placed on this activity structure, however, one participant indicated a score of 3 (neutral) and stated, “They both are great to consult and rich with different ideas and approaches” (P7, Storyline). The numerical score and comments seem contrary, but perhaps her comment reflects a larger perspective of interactions over the several years as she has participated in multiple CPET programs.

The remaining five activity structures and design supports were positive or very positive to all participants.

**Whole group interactions**

Evening group sharing session ($M = 4.30, SD = 0.48$), Informal Friday lunches ($M = 4.60, SD = 0.52$), and Presentation of designed unit ($M = 4.70, SD = 0.48$) all provided opportunities for interaction with peers in a whole group setting. During the evening group sharing session, the participants valued the “positive and effective feedback” (P4, Storyline) and the stimulation of ideas. The informal Friday lunches provided an opportunity “to meet those working in other labs” (P10, Storyline). On the final day of the TSP PD program, the presentations of the designed units allowed a chance for the participants to synthesize their curriculum and showcase their products. Laboratory hosts were invited to attend as well. This activity structure was viewed positively by all of the participants stating it “unified delivery of my own unit” (P8, Storyline) and was “nice to see what everyone did with their lab experience” (P6, Storyline). For some, the presentations were too long and they grew antsy to depart, but they still valued the activity as part of the TSP PD program.
Reflective journals

Participants completed electronic reflective journals ($M = 4.00$, $SD = 0.00$) on each of the first 12 days of the program. Even though some participants commented that they were “repetitive” (P4, Storyline), “redundant” (P2, Storyline), and disliked (P5, Storyline), they all valued the activity. Even the strong dislike was qualified “I hate reflections (doing them) but they force me to think - so it's good thing” (P5, Storyline). The daily reflections provided a structured way for the participants to consider their daily experiences and how they might influence their personal learning, pedagogical practices, and design decisions.

Informal conversations with peers

The overwhelmingly positive activity structure of the TSP PD program was informal conversations with peers ($M = 5.00$, $SD = 0.00$). Every participant scored this component as very positive and voiced “These were the best people in the world” (P2, Storyline). Although the participants valued all of the activity structures and design supports, it is the interactions with their fellow participants that are most valued. Collegiality with like-minded individuals provided needed support as participants grappled with translating their laboratory experience into a purposefully designed unit.

Analysis of Interviews

The semi-structured interviews were conducted with each participant individually and lasted between 45 minutes and 1.5 hours. The interviews were audio recorded with permission and transcribed for analysis. The interview script (Appendix J) focused on the role of the laboratory experience, colleagues, and the TSP PD program in their design process. HyperRESEARCH was used for qualitative analysis. A codebook (Appendix M) was generated based on the activity structures and design supports listed
in Table 3-1 and the storyline instrument (Appendix I). Each interview was first coded according to the type of structure or support referenced. If it was an affordance or constraint, that was coded as well. Often participants combined activity structures and design supports in a single statement. To maintain as much context as possible in such instances, multiple codes were assigned to a single sentence or phrase, such as if a participant referred to interactions with peers as a positive aspect for developing their curriculum, it was coded as collective participation, affordance, and curriculum writing. All source text was collected by code to isolate the statements so they could be compared for consistency in coding and recoded as needed. The components from the storyline were collapsed into the activity structures and design supports described in Table 3-1 to reduce the number of codes and the redundancy. For example, conversations with peers was a component on the storyline and a code used frequently during the first round of analysis. This is a form of collective participation and as such was included in this category during axial coding. All categories were perceived as both affordances and constraints. Each category is elaborated below.

**Subject matter learning**

This category incorporates subject matter knowledge and understanding of student conceptions. Within the TSP PD program, this was expected to occur during the laboratory experience and discussion with researchers and peers. Many participants shared detailed accounts of the activities taking place within their laboratory placement and commented on their increased depth of knowledge due to their laboratory experience as an affordance. Participant 8 shared that her placement in a research lab focused on transcription factors related to the regulation of different forms of hemoglobin, or more broadly, epigenetics, “…was perfect. It was definitely serendipity. It
was a gap in my understanding. Part of my content that I need to deliver but a gap in my comfort level in teaching that topic so for me it was ideal. It was perfect” (P8, Interview). Subject matter learning afforded the development of the participants’ designed curriculum by providing content but also considering the conceptions of their students. Participant 7 was placed in a research laboratory focused on proteomics that utilized plants as their system of study, specifically changes in photosynthetic pathways that are induced by changes in the climate. She commented “It allows to me to take something that is very high science which is what they are doing in the lab and …present it to the students without the students falling apart on me. I need to almost translate everything into their world. If I want to show them something that they will be interested in it has to be into their context, their world. C3 and CAM are not in their world” (P7, Interview).

The specificity of the research laboratory was a constraint to some participants as Participant 5 shared “They really focus on the splicing events and that is such a teeny, tiny part of what we teach” (P5, Interview). Some felt they lacked the necessary depth of knowledge to understand the laboratory focus and spent time in outside of the laboratory reviewing materials: “I didn’t comprehend on day one everything that was going on and it was frustrating to me. So it took probably three or four days to get adjusted to the lab and study background information to bring my brain up to speed on what was going on in the lab” (P1, Interview). Also considered a constraint to subject matter learning was the lack of hand-on experiences in the research laboratory and developing skills as Participant 6 explains “I did want to increase lab skills too although I don’t feel I got that this time. I did get academic knowledge” (P6, Interview). Participant 10 expressed frustration that the first week focused on theory and building her
background knowledge about linkage disequilibrium studies in poplar trees. Without the opportunity to experience the research methods described in the papers until week two of the program, she struggled to make connections to her classroom and developing curriculum.

**Active learning**

Active learning is operationalized in this study to include first person experiences with activities such as developing a multi-lesson unit and group discussion as well as first person experiences with the process of science. Several of the participants shared experiments they performed or commented on the practices and process of science taking place in their research laboratory. These experiences afforded their design expertise, allowing them to understand difficulties their students might experience and reacquaint them with the nature of science. During her time in an ecotoxicology laboratory, Participant 11 learned how to set-up serial dilutions of toxicants and perform an acute assay using *Daphnia* which she then incorporated as an activity in her designed curriculum. She faced challenges in her experimentation explaining

> I set up two experiments, the first one with potassium which is one of the ingredients of fertilizer. They all lived so our concentration wasn’t high enough and then the one we used with copper they all died so that one was too high. So we had to adjust and then the next time that we ran the experiment something happened. My control samples died which tells me something was wrong from the beginning. (P11, Interview)

Her engagement with active learning afforded her development of an assay for her students using household products without clear levels of toxicity for *Daphnia*. Similarly, other teachers seemed to appreciate seeing experiments not work in the laboratory and witnessing the protocol modification and troubleshooting that resulted. Active learning also afforded Participant 9 the opportunity to reconsider the sequencing of her
biotechnology course as they performed different procedures in the process of genome sequencing. She shared “(It) flipped my whole biotech II curriculum upside down about the way it really should be performed. That was interesting I’m like oh, I can’t do that here. I should be doing it here because that’s the application for it” (P9, Interview).

There was only one constraint associated with active learning as Participant 7 shared her struggles with designing and writing her curriculum to translate her research experience: “It’s like going through a new process. When you go through a new process you get frustrated and then you see that you can do it and then you get frustrated again.” However, she also recognizes this as the process of learning “Then you see you can really, really do it. It’s not that difficult” (P7, Interview). For Participant 7, it did not prevent her from designing a very successful product.

**Collective participation**

The participants in the TSP PD program were all experienced high school science teachers, which fostered collective participation. Participants were paired by the program staff and assigned to the same laboratory and adjoining dormitory suites to facilitate collaboration. The program staff paired participants in advance based on the subject taught, participant geographic location and school demographics, and past program participation. For example, Participants 5 and 6 were paired primarily because they were the only two IB Biology teachers and Participants 4 and 7 were paired primarily because they attended the 2015 TSP PD program and were familiar with each other. During the evening sessions, participants selected where they sat in groups of four and those became organic groups for group activities. Often laboratory pairs sat together, but just as often, they interspersed. Many of the participants shared that collective participation afforded their curriculum design as well as enjoyment of the
program. The participants talked about their laboratory partner and their interactions.

Participant 6 was placed in the same research laboratory as Participant 5, both teachers of IB level Biology.

We were sharing activities we do with each other. We were sharing websites we use. Talking about student problems and trying to get certain concepts across. We did a lot of that as well as talking about the lesson plans that we’re writing now. (P6, Interview)

For Participant 6, having another teacher who could relate to her specific context was “huge.” Participant 5 echoed these sentiments.

Even while we bounce things off with the curriculum we’re writing what do you think about this, we’ve shared so much other stuff. When I say something she gets what I am talking about. Where I don’t have to explain what I am talking about. It’s been really, really good. (P5, Interview)

The participants did not have to teach the same subject however to feel the pairing was an affordance. Participant 8 shared resources with Participant 1, Participant 3 and Participant 11 provided collegiality and comfort to each other in a new setting, and Participant 4 calmed Participant 7’s fears of working with plants while Participant 7 supported Participant 4’s understanding of chemistry. While she was in the lab, Participant 0 was able to clarify concepts and assist Participant 2 in reaching a deeper understanding of the genomics lab. One pairing (Participant 10 and Participant 9) was not as successful and for these two participants, collective participation was a constraint.

**Duration**

The duration of the program both afforded and constrained the participants’ development of design expertise. Many of the participants thought the length of time in the research laboratory was adequate to provide subject matter for their curriculum. Some participants felt they had enough time in both the research setting and focused
curriculum writing to complete the expectation of a 3-5 lesson unit. Participant 9 shared “Length of time I think was good” (P9, Interview). Similarly, Participant 8 agreed.

I think that’s plenty of time to write. My partner came up with a much easier approach, like for my anatomy class, I could have focused on the structure of human I could have made it so much simpler but I’ll be really happy with the epigenetics when I’m done. I ended up with six lessons but there are three activities in each lesson. So I think that’s what’s taking me such a long time, it’s taking me a full day to get them kind of the way I want them. (P8, Interview)

However, the designated last week of the program for curriculum writing constrained many of the participants. Some participants were still sorting out their ideas and meeting with their faculty host during the third week of the program which limited their writing time.

Today I got some information (from lab host) that now I have three days to put it down and revise it. You know make it work. I feel rushed. If I had the extra week I wouldn’t feel like I’m feeling right now. I’m like oh I’m going to write oh no I need to meet Julie. I want to make sure everything he told us is there but I know that I have a deadline that is in two days. (P7, Interview)

Participant 5 also felt her curriculum was not as finished as she would have like.

I wish because now its crunch time and there’s just not enough time to do what I think I need to do. I know it’s very unpolished and I think that bothers me. It’s very rough. (P5, Interview)

Participant 1 suggested she would have liked more time not because she was feeling constrained to finish her 3-5 lessons, but that she would like to include more lessons and another week on campus would have allowed her to do so.

I would have liked another week to write and write more. Make a bigger, longer unit with more lessons. I think that because I have heard a lot of teachers say well I have like eight ideas or ten ideas and now I have to narrow down. Another week of writing would produce more curriculum materials. (P1, Interview)
The participants were expected to submit a near final draft on the last day of the program, but for those who wanted to make additional changes, they were given extra time and asked to submit their final draft within two weeks. It is interesting that the participants found the duration an affordance as it gave them a deadline to meet and encouraged their curriculum writing but at the same time a constraint that did not allow them to fully develop their ideas. However, even though they were given time beyond the three-week campus TSP PD program to modify and resubmit, none did so.

**Coherence**

Coherence is a unique construct. It is an activity structure according to Penuel and colleagues (2011) as it is one of the critical features of high quality professional development. However, within this study, it is also a design support as it attends to the internal consistency of the curriculum and the extent to which the curriculum aligns with local, state, and national standards. Therefore, coherence is an activity structure that is also a design support as it attends to the extent that the TSP PD program is aligned to the standards and pacing guides as well as the expectations of the participant’s school community. Some teachers explicitly mentioned the use of their district’s pacing guide to inform their curriculum as an affordance. Participant 11 drew resources from the pacing guide such as essential questions and vocabulary and built her lessons around district expectations. Participant 10 also utilized her district’s pacing guide stating “I came with my actual pacing guide and figured out what benchmarks I would hit in teaching this information and how long it would take me to actually do it” (P10, Interview).

Additionally, providing a curricular template for all participants to use provides design support and scaffolding to novice curriculum designers and helps participants to understand the expectations of the program and the program coordinators. After talking
about previous design experience Participant 2 had with another PD program, he shared the following insight regarding his perspective of coherence as an affordance in the TSP PD program of this study:

I appreciate very much that you gave us this because I'll tell you the truth on the other things that we were talking about before where we did lesson planning and that kind of thing there wasn't really a template given and that kind of made you have the feeling that well they’re sitting there with the attitude that you are going to do something and they have to have that for their part of the grant and whatever you give them they are going to criticize it which criticism is part of it anyway but you just got that idea that it was more the process and less the idea of idealistically creating something that was useful and reusable. (P2, Interview)

The participants shared constraints of coherence as well related to the curriculum template. Several of the teachers shared that the format of the lessons was not coherent with their district’s expectations, specifically that they were much too long and in depth for their administration. Participant 7 believed that she would have to rewrite her curriculum when she implements in classroom to conform to the district requirements “…what we’re doing now is not in a lesson format that we are expected to have. So if I’m going to do it I still need to do lesson plans I would probably cut and paste but I still need to put it in the (district) template” (P7, Interview). Similarly, Participant 9 shared “I may have to revise like if I had to hand my lesson plans in to my administrator I need a one piece page or two page document that I need to give them like stuff they are going to evaluate me on” (P9, Interview). The curriculum template and the design sessions attempted to scaffold participant design and development of educative curricular materials that would provide other users the opportunity to deepen their subject matter knowledge as well as pedagogical content knowledge. However, Participant 6 did not adopt this perspective and shared that she perceived the template as a constraint.
P6: There’s some components that I’m not sure I like.

Interviewer: Such as?

P6: I put all my background information in the beginning and I don’t want to rewrite it in every section. So I just put a note refer to the background information section. (P6, Interview)

Unfortunately, it seems she did not understand the template and the idea of educative materials, which provide deeper background information relevant to each lesson. This was reflected in the SLPAI score for the curriculum as she only included general background information from her textbook at the beginning of her curriculum and did not demonstrate adequate subject matter knowledge for the lessons. Lastly, some participants had technology issues. Participant 9 shared that she had difficulty working within the MS Word document template and opted to create a separate document that did not have formatting already included.

**Role of program**

The role of program includes the personal resources dedicated and activities planned by the program staff to scaffold and facilitate the development of the participants’ design expertise. Within the current TSP PD program, the role of program included structured activity development time, design task assignments, and feedback from program coordinators. There were few coded responses for this category that related the participants’ perspectives on how the role of the program afforded or constrained their design expertise. Participant 3 was one of the few to explicitly connect the structured activity development time as affording her design by giving her a relaxed yet structured setting to allow her mind to process all that she had seen and done in her research laboratory.
I didn’t have a clue where I was going with my curriculum until like 5 o’clock that afternoon and I knew that I was going to have to do an overview and I was like oh no but having that relaxed situation that it just clicked, it just came, I was able to process. (P3, Interview)

She further emphasized the importance of the structured evening sessions focused on design and how she perceived them as an affordance.

I’m thinking more particularly the evening sessions they were informal but I thought extremely helpful and productive like with the articles that we had and it’s something that I typically wouldn’t have expected that I would have enjoyed those programs and those sessions but that was wonderful. (P3, Interview)

In addition to structured group sessions, participants and coordinators had opportunities to discuss progress and concerns related to curriculum development through email, face-to-face meetings, and informal conversations during laboratory visits, Friday lunches, and group sessions. Not everyone attended the optional one-on-one sessions but Participant 9 shared “it’s good that we are meeting with you guys individually” (P9, Interview). She did not elaborate, so it is unclear why she perceived this to be an affordance. For others, the TSP PD program could have provided more scaffolding and structured development activity time. Participant 8 appreciated the design tasks and suggested that she would have liked to have been encouraged to write sooner rather than starting design task assignments the second week of the TSP PD program.

I’m using a lot of the things we wrote last week. Those products that we produced. I’m altering them a little bit and pulling them in and using them. I think even more foresight more forethinking maybe the first week. I took lots of notes. Pages and pages and pages of notes the first week so I am going back and looking at those but I think maybe synthesizing those in some other way. It would have been not a huge assignment every night but something to force us to be a little more reflective of our experience in the lab not the philosophical ideas of the learning objectives necessarily but a product maybe. I don’t know what that would look like but even earlier writing. I would have been okay with even earlier submissions just to get the ball rolling in your brain. (P8, Interview)
Similarly, Participant 10 suggested more time for reflection in small groups or pairs.

I would probably suggest adding a little bit more. If we are doing half of a day of okay you need to be in the lab you are doing this or that there should be some time for debriefing one way or the other because realistically when you are working with one person who has not been in the classroom, it’s difficult to debrief or figure out what’s going on. After the lab if you would have a time for debriefing with other educators where you can actually mingle and figuring out or bounce ideas it would probably make it easier for the curriculum development part. (P10, Interview)

Her perspective is interesting in light of her laboratory placement and the difficulties she had with her partner. Both she and her partner, Participant 9, commented on constraints of collective participation. This comment could reflect her perception of isolation in the program due to incompatibility with her laboratory partner.

**Models and materials**

Reference to teacher created and found lessons, textbooks, and exemplar curricular materials were coded as the design support models and materials. Participant 8 mentioned she brought the textbook for her Honors Genetics course that she utilized and shared with her laboratory partner Participant 1 as they were both learning more about epigenetics. Participants also utilized materials from other sources such as the Learn.Genetics website (http://learn.genetics.utah.edu/) and biotechnology kits from Carolina Biological such as Participant 10’s use of Wisconsin Fast Plants. These materials afforded their design expertise by providing content and activities for inclusion in their developing curriculum. Participants also created their own materials and modified the exemplar curriculum used as the program model. Participant 11 shared how she developed elements of her curriculum: “I thought that would hook them and then let’s identify [macroinvertebrates] and then the next was let’s read about toxins and you had a jigsaw reading in Pompe so I’m like let’s do that” (P11, Interview). She also
spent a great deal of time determining what similar activities had already been developed using *Daphnia* as a bioindicator species with the aim of creating something unique for her classroom context. She stated, “I looked at what has been done. A lot of it is with chlorine, a lot of it with salt, experiments with looking at the heart rate and looking at nicotine which is all great but I wanted something different” (P11, Interview).

The exemplar curriculum (*The Pompe Predicament*) used as the program model was a constraint for some participants due to the number of lessons. Participant 7 was one of the most emphatic saying “The Pompe Predicament seems like it’s overwhelming. … every time I pick up the book it’s like oh my gosh look at all these pages” (P7, Interview). Creating new materials was also a constraint for some as this was the first time they had been tasked with designing a learning module based on a research experience. It was Participant 5 who expressed this notion succinctly: “I’m use to stealing and adapting. So starting from scratch is time consuming, which is why I steal and adapt cause who has time to do this for everything?” (P5, Interview). Similarly, Participant 9 revealed that she is “…not use to making teacher answer keys” (P9, Interview) which was part of the exemplar curricular model.

**Explicit design model**

To foster development of design expertise, an explicit design model was used during the program through activities and discussions of journal articles including aspects of *Understanding by Design*, inclusion of the ADDIE model as primer to design (Hardre, 2003), designing learning-goals driven educative materials (Reiser et al., 2003 Krajcik et al., 2008) and heuristics for developing educative curricular materials (Davis & Krajcik, 2005). References to any of these items were coded as explicit design model. Participant 10 shared her thought process behind the design and development of her
curriculum, which adopted the explicit design model encouraged during the TSP PD program.

I had to look at the overall goal because I wanted to figure out where am I going to end up and then go backward in figuring out from the goal what is it I need the students to understand or master in order for them to understand the overall goal of where I needed them to be. It’s more like okay I have an actual concept and I know that goal that needs to be understood before that concept can make sense and then working backward and figure out what are the key things I need to focus on to get that across to my students. (P10, Interview)

Similarly, Participant 8 shared her backwards thinking and how the explicit design model afforded her design expertise.

I’ve always looked at standards. I use standard based instruction. I don’t know how anybody couldn’t but evidently people don’t. It’s forced me to really pay attention to the standards. It has forced to me to take the understanding by design, which I’ve done in the past to develop my own little units. Kind of thinking about thinking for myself and putting that all together to design a lesson plan rather than just I want them to learn this this is how I can get them to get there let’s just do that. It’s more in depth thinking about how the lesson is going to be structured. I’m not just looking at the final end product. I’m looking at all the little baby steps we do to get there and how I can assess their learning in each of the baby steps to make sure they are ready to go on to the next step. (P8, Interview)

One participant in particular specifically referenced the change in her design process and how the explicit design model afforded her design expertise so that she was more focused on student understanding.

Interviewer:  What came first? The activities or your learning goals?

P3: If I hadn’t read the article that you recommended before we went into it I would have said probably half and half. It’s difficult to separate the two. After reading the article and some of the activities that we did in our evening sessions that’s when I started focusing oh yes I love to have fun and I love my kids to have fun and I want them to have that success but I also want it to translate in are they taking away from this lesson actual content or meat that they can show that they have learned that information. So it helped to settle me down and to focus on that part because I get all excited oh let’s do this but I need to kind of become more grounded. (P3, Interview)
Participant 7 shared that for this TSP PD program, she designed her curriculum in a learning-goals driven manner due to the specific design task assignments that forced her to think in a different sequence.

I think of the activity first and then I see which are going to be the goals and then I tie the standards in there. Even though to be honest with you I didn’t do that this time because you had us pull the standards first. Normally I wouldn’t do it that way because the homework was due for the standards I pulled all the standards and then I said okay I’m going to do that but I already had in my head what activities were going to be so still I had the activities first and then I did the alignment to the standards. The activities weren’t developed but I had a pretty good rough idea what I was going to do. (P7, Interview)

Participant 7 was able to use the explicit design model successfully, but it constrained her normal process of developing learning episodes for her students. Participant 7’s comments also reinforce Participant 3’s notion that often activities and goals are intertwined, perhaps more so during a TSP PD program which tasks participants with translating their research experience into a designed curriculum for their classroom.

Some inductive codes were also generated during the first round of coding such as PD needs, improve teaching, and excitement to capture particular teacher perceptions that could influence their participation in the program, however these were not further analyzed as they are beyond the scope of the research question but they are discussed in the next chapter.

**Conclusion**

This chapter presented the results of the study. Based on the instruments used, there was no difference in subject matter knowledge and pedagogical content knowledge. However, there was a gain in curriculum design knowledge. Considering the participants’ ratings and comments on their daily reflective journals, they reveal that they perceive differences in their personal learning, pedagogical practices, and
instructional design decisions as a result of the TSP PD program. All of the participants demonstrated a successful level of design expertise, which blends elements of SMK, PCK, and CDK, producing novel designed curricula for use in their classrooms. Drawing from the quantitative scores, it appears that in this study curriculum design knowledge-the knowledge and skills required to enact the design of learning experiences which are consistent with local and national education contexts using a systematic design approach-was the most important influence on design expertise-the required skills and knowledge needed to purposefully design quality curriculum materials and learning experiences for the science classroom. While participants drew upon their SMK and PCK in the development of their curriculum, it was CDK that facilitated their logical and purposeful design of new learning episodes. Lastly, the perceptions of the participants indicate that they felt all of the activity structures and design supports of the TSP PD program were both affordances and constraints to their design expertise and overall experience with the TSP PD program. The next chapter discusses these results further with implications for future investigation and practical application.
<table>
<thead>
<tr>
<th>Participant</th>
<th>SMK-Total</th>
<th>SMK-Multiple Choice</th>
<th>SMK-Free Response Question</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Gain</td>
</tr>
<tr>
<td>P1</td>
<td>15</td>
<td>19</td>
<td>4</td>
</tr>
<tr>
<td>P2</td>
<td>16</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>P3</td>
<td>12</td>
<td>17</td>
<td>5</td>
</tr>
<tr>
<td>P4</td>
<td>15</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>P5</td>
<td>24</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>P6</td>
<td>26</td>
<td>24</td>
<td>-2</td>
</tr>
<tr>
<td>P7</td>
<td>19</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td>P8</td>
<td>19</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>P9</td>
<td>11</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>P10</td>
<td>9</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>P11</td>
<td>13</td>
<td>14</td>
<td>1</td>
</tr>
</tbody>
</table>

Mean: 16.27 (SD 5.31) 17.45 (SD 4.23) 1.18 (SD 1.99) 12.09 (SD 2.91) 12.63 (SD 2.20) 0.55 (SD 1.21) 4.18 (SD 2.79) 4.82 (SD 2.32) 0.64 (SD 1.21)

Normalized: 0.09 0.09 0.08

Maximum scores SMK-Total = 30, SMK-Multiple Choice = 18, SMK-Free Response Question = 12
Table 4-2. PRIME PCK reflection scores on protein synthesis as a measure of PCK.

<table>
<thead>
<tr>
<th>Participant</th>
<th>PCK-Total</th>
<th>PCK-Content Knowledge</th>
<th>PCK-Pedagogical Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Gain</td>
</tr>
<tr>
<td>P1</td>
<td>12</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>P2</td>
<td>10</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>P3</td>
<td>10</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>P4</td>
<td>13</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>P5</td>
<td>7</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>P6</td>
<td>13</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>P7</td>
<td>9</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>P8</td>
<td>16</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>P9</td>
<td>11</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>P10</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>P11</td>
<td>10</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Mean</td>
<td>10.55</td>
<td>10.91</td>
<td>0.36</td>
</tr>
<tr>
<td>(SD)</td>
<td>(3.01)</td>
<td>(3.21)</td>
<td>(0.67)</td>
</tr>
<tr>
<td>Normalized</td>
<td>0.03</td>
<td>0.02</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Maximum scores PCK-Total = 24, PCK-Content Knowledge = 12, PCK-Pedagogical Knowledge = 12
Table 4-3. CDK survey scores as a measure of curriculum design knowledge.

<table>
<thead>
<tr>
<th>Participant</th>
<th>CDK-Pre</th>
<th>CDK-Retro</th>
<th>CDK-Post</th>
<th>Gain Pre: Retro</th>
<th>Gain Pre: Post</th>
<th>Gain Retro: Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>78</td>
<td>75</td>
<td>90</td>
<td>-3</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>P2</td>
<td>76</td>
<td>75</td>
<td>75</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>P3</td>
<td>67</td>
<td>59</td>
<td>72</td>
<td>-8</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>P4</td>
<td>79</td>
<td>82</td>
<td>89</td>
<td>3</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>P5</td>
<td>78</td>
<td>78</td>
<td>87</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>P6</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>P7</td>
<td>76</td>
<td>74</td>
<td>85</td>
<td>-2</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>P8</td>
<td>80</td>
<td>70</td>
<td>90</td>
<td>-10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>P9</td>
<td>88</td>
<td>78</td>
<td>87</td>
<td>-10</td>
<td>-1</td>
<td>9</td>
</tr>
<tr>
<td>P10</td>
<td>82</td>
<td>78</td>
<td>88</td>
<td>-4</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>P11</td>
<td>70</td>
<td>56</td>
<td>81</td>
<td>-14</td>
<td>11</td>
<td>25</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>78.27 (6.28)</td>
<td>73.82 (9.21)</td>
<td>84.64 (6.09)</td>
<td>-4.45 (5.30)</td>
<td>6.36 (4.95)</td>
<td>10.82 (7.51)</td>
</tr>
<tr>
<td>Normalized</td>
<td>-0.38</td>
<td>0.54</td>
<td>0.67</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Maximum score CDK = 24
Table 4-4. Results of related samples Wilcoxon Signed Rank test for curriculum design knowledge

<table>
<thead>
<tr>
<th>Pair</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Mean</th>
<th>SD</th>
<th>T</th>
<th>Sig</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CDK_post</td>
<td>CDK_post</td>
<td>84.636</td>
<td>6.087</td>
<td>52</td>
<td>0.012*</td>
<td>0.533</td>
</tr>
<tr>
<td></td>
<td>CKD_pre</td>
<td></td>
<td>78.272</td>
<td>6.278</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>CDK_post</td>
<td>CDK_retropre</td>
<td>84.636</td>
<td>6.087</td>
<td>45</td>
<td>0.008*</td>
<td>0.569</td>
</tr>
<tr>
<td></td>
<td>CDK_retropre</td>
<td></td>
<td>73.818</td>
<td>9.206</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < 0.05 (2-sided)
Figure 4-1. Participant mean level of agreement for each CDK element at pre, retrospective, and post administrations.
Table 4-5. Individual item scores based on CDK survey responses

<table>
<thead>
<tr>
<th>#</th>
<th>CDK element</th>
<th>Pre Mean</th>
<th>Pre SD</th>
<th>Retro Mean</th>
<th>Retro SD</th>
<th>Post Mean</th>
<th>Post SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Develop goals, objectives, and pacing for curricular units &lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.73</td>
<td>0.65</td>
<td>5.09</td>
<td>0.70</td>
<td>5.82</td>
<td>0.40</td>
</tr>
<tr>
<td>2</td>
<td>Define a problem statement prior to the design of a curricular unit &lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.27</td>
<td>0.65</td>
<td>5.18</td>
<td>0.60</td>
<td>5.73</td>
<td>0.47</td>
</tr>
<tr>
<td>3</td>
<td>Identify and link groups of related standards and benchmarks &lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.45</td>
<td>0.69</td>
<td>5.18</td>
<td>0.60</td>
<td>5.73</td>
<td>0.47</td>
</tr>
<tr>
<td>4</td>
<td>Analyze state standards to identify each concept addressed within &lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.27</td>
<td>0.65</td>
<td>5.36</td>
<td>0.50</td>
<td>5.73</td>
<td>0.47</td>
</tr>
<tr>
<td>5</td>
<td>Create learning objectives which address each concept within the standards &lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.18</td>
<td>0.75</td>
<td>5.27</td>
<td>0.65</td>
<td>5.73</td>
<td>0.47</td>
</tr>
<tr>
<td>6</td>
<td>Design activities which follow a learning progression &lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.18</td>
<td>0.40</td>
<td>4.82</td>
<td>0.87</td>
<td>5.73</td>
<td>0.47</td>
</tr>
<tr>
<td>7</td>
<td>Adapt curriculum materials to make them relevant for my students, school, or community &lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.36</td>
<td>0.50</td>
<td>5.09</td>
<td>0.70</td>
<td>5.82</td>
<td>0.40</td>
</tr>
<tr>
<td>8</td>
<td>Design curriculum materials that align learning goals, assessment, and learning outcomes &lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.18</td>
<td>0.60</td>
<td>4.82</td>
<td>1.08</td>
<td>5.64</td>
<td>0.50</td>
</tr>
<tr>
<td>9</td>
<td>Apply a logical, orderly method of identifying, developing and evaluating a set of planned strategies targeted for attaining the curricular goals &lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.82</td>
<td>0.60</td>
<td>4.55</td>
<td>1.21</td>
<td>5.64</td>
<td>0.67</td>
</tr>
<tr>
<td>10</td>
<td>Clarify instructional problems and objectives and identify the learners’ existing knowledge and skills before developing or adapting learning activities &lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.73</td>
<td>0.47</td>
<td>4.55</td>
<td>0.69</td>
<td>5.45</td>
<td>0.69</td>
</tr>
<tr>
<td>11</td>
<td>During the design of a curricular unit, identify learning objectives, assessment instruments, and learning exercises &lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.27</td>
<td>0.47</td>
<td>4.91</td>
<td>0.70</td>
<td>5.64</td>
<td>0.67</td>
</tr>
<tr>
<td>12</td>
<td>Create and assemble learning materials for a curricular unit based on the design plan &lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.36</td>
<td>0.67</td>
<td>4.82</td>
<td>0.98</td>
<td>5.64</td>
<td>0.67</td>
</tr>
<tr>
<td>13</td>
<td>Engage in formative evaluation of a curricular unit by taking learners’ experiences and learning outcomes into account &lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.09</td>
<td>0.54</td>
<td>4.64</td>
<td>1.03</td>
<td>5.55</td>
<td>0.52</td>
</tr>
<tr>
<td>14</td>
<td>Engage in summative evaluation of a curricular unit in order to assess student learning outcomes &lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.09</td>
<td>0.30</td>
<td>4.73</td>
<td>1.01</td>
<td>5.36</td>
<td>0.81</td>
</tr>
<tr>
<td>15</td>
<td>Generate ideas about how to make improvements to a curricular unit &lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.27</td>
<td>0.65</td>
<td>4.82</td>
<td>0.75</td>
<td>5.45</td>
<td>0.52</td>
</tr>
</tbody>
</table>

Total score: 78.27 Pre, 6.28 Pre SD, 73.82 Retro, 9.21 Retro SD, 84.64 Post, 6.09 Post SD

<sup>a</sup> Huizinga, 2014; <sup>b</sup> Reiser et al., 2003; Krajcik et al., 2008; <sup>c</sup> Hardre, 2003

Means based on Likert response scale: 6 = Strongly agree, 5 = Agree, 4 = Slightly agree, 3 = Slightly disagree, 2 = Disagree, 1 = Strongly disagree
<table>
<thead>
<tr>
<th>#</th>
<th>CDK element</th>
<th>Pre:Post</th>
<th>Retro:Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Develop goals, objectives, and pacing for curricular units a</td>
<td>0.10</td>
<td>0.80</td>
</tr>
<tr>
<td>2</td>
<td>Define a problem statement prior to the design of a curricular unit a</td>
<td>0.56</td>
<td>0.67</td>
</tr>
<tr>
<td>3</td>
<td>Identify and link groups of related standards and benchmarks b</td>
<td>0.34</td>
<td>0.67</td>
</tr>
<tr>
<td>4</td>
<td>Analyze state standards to identify each concept addressed within b</td>
<td>0.72</td>
<td>0.58</td>
</tr>
<tr>
<td>5</td>
<td>Create learning objectives which address each concept within the standards b</td>
<td>0.75</td>
<td>0.63</td>
</tr>
<tr>
<td>6</td>
<td>Design activities which follow a learning progression b</td>
<td>0.47</td>
<td>0.77</td>
</tr>
<tr>
<td>7</td>
<td>Adapt curriculum materials to make them relevant for my students, school, or community b</td>
<td>0.51</td>
<td>0.80</td>
</tr>
<tr>
<td>8</td>
<td>Design curriculum materials that align learning goals, assessment, and learning outcomes b</td>
<td>0.39</td>
<td>0.69</td>
</tr>
<tr>
<td>9</td>
<td>Apply a logical, orderly method of identifying, developing and evaluating a set of planned strategies targeted for attaining the curricular goals c</td>
<td>0.57</td>
<td>0.75</td>
</tr>
<tr>
<td>10</td>
<td>Clarify instructional problems and objectives and identify the learners’ existing knowledge and skills before developing or adapting learning activities c</td>
<td>0.50</td>
<td>0.62</td>
</tr>
<tr>
<td>11</td>
<td>During the design of a curricular unit, identify learning objectives, assessment instruments, and learning exercises b</td>
<td>0.34</td>
<td>0.67</td>
</tr>
<tr>
<td>12</td>
<td>Create and assemble learning materials for a curricular unit based on the design plan a</td>
<td>0.24</td>
<td>0.69</td>
</tr>
<tr>
<td>13</td>
<td>Engage in formative evaluation of a curricular unit by taking learners’ experiences and learning outcomes into account a</td>
<td>0.34</td>
<td>0.67</td>
</tr>
<tr>
<td>14</td>
<td>Engage in summative evaluation of a curricular unit in order to assess student learning outcomes b</td>
<td>0.21</td>
<td>0.50</td>
</tr>
<tr>
<td>15</td>
<td>Generate ideas about how to make improvements to a curricular unit a</td>
<td>0.15</td>
<td>0.53</td>
</tr>
</tbody>
</table>

a Huizinga, 2014; b Reiser et al., 2003; Krajcik et al., 2008; c Hardre, 2003
<table>
<thead>
<tr>
<th>Data point</th>
<th>Program Date</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>Day 1</td>
<td>Orientation</td>
</tr>
<tr>
<td>1</td>
<td>Day 2</td>
<td>Laboratory</td>
</tr>
<tr>
<td>2</td>
<td>Day 2 evening</td>
<td>Evening session: Sharing lab overviews; Heuristics for educative materials (Davis &amp; Krajcik, 2005) and learning-goals oriented curriculum development (Krajcik et al., 2008)</td>
</tr>
<tr>
<td>3</td>
<td>Day 3</td>
<td>Laboratory</td>
</tr>
<tr>
<td>4</td>
<td>Day 4</td>
<td>Laboratory</td>
</tr>
<tr>
<td>5</td>
<td>Day 4 evening</td>
<td>Evening session: Sharing lab updates; UbD design standards (Wiggins &amp; McTighe, 2001); curriculum design expertise (Hardre, 2003); peer review of model curriculum using design standards</td>
</tr>
<tr>
<td>6</td>
<td>Day 5</td>
<td>Laboratory; Informal lunch w/ all labs</td>
</tr>
<tr>
<td>7</td>
<td>Day 6</td>
<td>Laboratory</td>
</tr>
<tr>
<td>8</td>
<td>Day 7</td>
<td>Laboratory</td>
</tr>
<tr>
<td>9</td>
<td>Day 7 evening</td>
<td>Evening session: Posters summarizing curriculum, share out, gallery walk with post-it comments</td>
</tr>
<tr>
<td>10</td>
<td>Day 8</td>
<td>Laboratory</td>
</tr>
<tr>
<td>11</td>
<td>Day 9</td>
<td>Laboratory; Informal lunch w/ all labs</td>
</tr>
<tr>
<td>12</td>
<td>Day 10</td>
<td>Individual curriculum design</td>
</tr>
<tr>
<td>13</td>
<td>Day 11</td>
<td>Individual curriculum design</td>
</tr>
<tr>
<td>14</td>
<td>Day 12</td>
<td>Content presentation and lunch discussion with faculty researcher</td>
</tr>
<tr>
<td>**</td>
<td>Day 13</td>
<td>Group curriculum discussion session</td>
</tr>
<tr>
<td>**</td>
<td>Day 14</td>
<td>Curriculum presentations</td>
</tr>
<tr>
<td>*</td>
<td>Day 20</td>
<td>Post program survey for additional demographic information and unique identifier</td>
</tr>
</tbody>
</table>

*No prompts about changes in professional knowledge

**No reflective journal
<table>
<thead>
<tr>
<th>Data point</th>
<th>Date</th>
<th>Learning*</th>
<th>Pedagogical practices*</th>
<th>Instructional design decisions*</th>
<th>Engagement**</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Day 2</td>
<td>3.90</td>
<td>3.00</td>
<td>2.91</td>
<td>4.00</td>
</tr>
<tr>
<td>2</td>
<td>Day 2 evening</td>
<td>4.00</td>
<td>3.80</td>
<td>3.70</td>
<td>4.80</td>
</tr>
<tr>
<td>3</td>
<td>Day 3</td>
<td>3.82</td>
<td>4.00</td>
<td>3.91</td>
<td>4.36</td>
</tr>
<tr>
<td>4</td>
<td>Day 4</td>
<td>3.82</td>
<td>3.36</td>
<td>3.10</td>
<td>4.36</td>
</tr>
<tr>
<td>5</td>
<td>Day 4 evening</td>
<td>4.17</td>
<td>3.67</td>
<td>4.08</td>
<td>4.58</td>
</tr>
<tr>
<td>6</td>
<td>Day 5</td>
<td>3.82</td>
<td>3.90</td>
<td>3.82</td>
<td>4.18</td>
</tr>
<tr>
<td>7</td>
<td>Day 6</td>
<td>4.13</td>
<td>4.13</td>
<td>4.13</td>
<td>4.57</td>
</tr>
<tr>
<td>8</td>
<td>Day 7</td>
<td>3.89</td>
<td>3.88</td>
<td>3.88</td>
<td>4.50</td>
</tr>
<tr>
<td>9</td>
<td>Day 7 evening</td>
<td>3.75</td>
<td>4.43</td>
<td>4.25</td>
<td>5.00</td>
</tr>
<tr>
<td>10</td>
<td>Day 8</td>
<td>3.45</td>
<td>3.60</td>
<td>4.22</td>
<td>4.00</td>
</tr>
<tr>
<td>11</td>
<td>Day 9</td>
<td>3.57</td>
<td>3.71</td>
<td>3.71</td>
<td>4.25</td>
</tr>
<tr>
<td>12</td>
<td>Day 10</td>
<td>3.82</td>
<td>3.45</td>
<td>4.00</td>
<td>4.82</td>
</tr>
<tr>
<td>13</td>
<td>Day 11</td>
<td>4.40</td>
<td>4.30</td>
<td>3.90</td>
<td>4.70</td>
</tr>
<tr>
<td>14</td>
<td>Day 12</td>
<td>3.78</td>
<td>3.33</td>
<td>3.89</td>
<td>4.37</td>
</tr>
<tr>
<td>Total (SD)</td>
<td></td>
<td>3.88 (0.24)</td>
<td>3.75 (0.39)</td>
<td>3.82 (0.39)</td>
<td>4.46 (0.30)</td>
</tr>
</tbody>
</table>

*Likert response scale: 0 = Not applicable, 1 = Very unsuccessful, 2 = Unsuccessful, 3 = Neither successful nor unsuccessful, 4 = Successful, and 5 = Very successful; **Likert response scale: 0 = Not applicable, 1 = Not at all engaged, 2 = Not engaged, 3 = Neutral, 4 = Somewhat engaged, and 5 = Very engaged.
Figure 4-2. Reflective journal Likert scale response means.
Table 4-9. SLPAI scores as an indicator of design expertise

<table>
<thead>
<tr>
<th>Participant</th>
<th>Weighted</th>
<th>Normalized</th>
<th>Success category</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>50</td>
<td>68</td>
<td>Highly successful</td>
</tr>
<tr>
<td>P2</td>
<td>38</td>
<td>56</td>
<td>Successful</td>
</tr>
<tr>
<td>P3</td>
<td>60</td>
<td>78</td>
<td>Highly successful</td>
</tr>
<tr>
<td>P4</td>
<td>61</td>
<td>79</td>
<td>Highly successful</td>
</tr>
<tr>
<td>P5</td>
<td>35</td>
<td>53</td>
<td>Successful</td>
</tr>
<tr>
<td>P6</td>
<td>34</td>
<td>52</td>
<td>Successful</td>
</tr>
<tr>
<td>P7</td>
<td>77</td>
<td>95</td>
<td>Highly successful</td>
</tr>
<tr>
<td>P8</td>
<td>82</td>
<td>100</td>
<td>Highly successful</td>
</tr>
<tr>
<td>P9</td>
<td>36</td>
<td>54</td>
<td>Successful</td>
</tr>
<tr>
<td>P10</td>
<td>68</td>
<td>86</td>
<td>Highly successful</td>
</tr>
<tr>
<td>P11</td>
<td>44</td>
<td>62</td>
<td>Successful</td>
</tr>
</tbody>
</table>

Mean (sd) 71.18 (17.44)

Level of success based on Brown et al., 2014: highly successful (67–100), successful (39–66) and minimally successful (0–38)
Table 4-10. SLPAI criteria, knowledge alignment, and category scores

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Professional Knowledge</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment with Endorsed Practices</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 Alignment with standards</td>
<td>CDK</td>
<td>1.91</td>
<td>0.30</td>
</tr>
<tr>
<td>1.2 Awareness of science education research</td>
<td>PK</td>
<td>1.27</td>
<td>0.65</td>
</tr>
<tr>
<td>Lesson Design and Implementation—Cognitive and Metacognitive Issues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 Goal orientation</td>
<td>CDK</td>
<td>1.27</td>
<td>0.47</td>
</tr>
<tr>
<td>2.2 Content accuracy</td>
<td>PCK-CK, SMK</td>
<td>1.00</td>
<td>0.77</td>
</tr>
<tr>
<td>2.3 Content presentation</td>
<td>PCK-CK</td>
<td>1.27</td>
<td>0.90</td>
</tr>
<tr>
<td>2.4 Preassessment</td>
<td>CDK, PCK-CxK, PCK-PK</td>
<td>0.45</td>
<td>0.52</td>
</tr>
<tr>
<td>2.5 Meaningful application</td>
<td>CDK, PCK-CK</td>
<td>1.73</td>
<td>0.47</td>
</tr>
<tr>
<td>2.6 Student reflection</td>
<td>PCK-PK</td>
<td>1.27</td>
<td>0.65</td>
</tr>
<tr>
<td>2.7 Assessment</td>
<td>CDK</td>
<td>1.18</td>
<td>0.60</td>
</tr>
<tr>
<td>Lesson Design and Implementation—Sociocultural and Affective Issues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1 Equity</td>
<td>PK</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>3.2 Student attitudes about science</td>
<td>PCK-CK, PCK for science topics</td>
<td>0.73</td>
<td>0.47</td>
</tr>
<tr>
<td>3.3 Student engagement</td>
<td>PCK-PK</td>
<td>1.55</td>
<td>0.52</td>
</tr>
<tr>
<td>3.4 Student participation</td>
<td>PCK-PK</td>
<td>1.64</td>
<td>0.50</td>
</tr>
<tr>
<td>3.5 Classroom discourse—Fostering a community of learners</td>
<td>PCK-PK</td>
<td>1.18</td>
<td>0.75</td>
</tr>
<tr>
<td>3.6 Appropriate use of technology</td>
<td>PK</td>
<td>1.73</td>
<td>0.47</td>
</tr>
<tr>
<td>3.7 Adaptability</td>
<td>PK</td>
<td>1.09</td>
<td>0.54</td>
</tr>
<tr>
<td>3.8 Variety and innovation</td>
<td>PCK-PK</td>
<td>1.27</td>
<td>0.79</td>
</tr>
<tr>
<td>Portrayal and Use of the Practices of Science</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.1 Use of hands-on exploration</td>
<td>PCK-PK</td>
<td>1.09</td>
<td>0.54</td>
</tr>
<tr>
<td>4.2 Nature of science</td>
<td>PCK-CK, PCK for scientific inquiry</td>
<td>0.91</td>
<td>0.83</td>
</tr>
<tr>
<td>4.3 Student practitioners of scientific inquiry</td>
<td>PCK-PK, PCK for scientific inquiry</td>
<td>1.18</td>
<td>0.60</td>
</tr>
<tr>
<td>4.4 Analytical skills</td>
<td>PCK for scientific inquiry</td>
<td>1.45</td>
<td>0.52</td>
</tr>
<tr>
<td>4.5 Error analysis</td>
<td>PCK for scientific inquiry</td>
<td>0.27</td>
<td>0.65</td>
</tr>
</tbody>
</table>
Table 4-11. Storyline activity structures and design supports

<table>
<thead>
<tr>
<th>Component</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory experience</td>
<td>3.00</td>
<td>5.00</td>
<td>4.30</td>
<td>0.82</td>
</tr>
<tr>
<td>Daily reflection</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Evening sessions (design)</td>
<td>3.00</td>
<td>5.00</td>
<td>4.00</td>
<td>0.67</td>
</tr>
<tr>
<td>Former intern</td>
<td>3.00</td>
<td>5.00</td>
<td>4.20</td>
<td>0.79</td>
</tr>
<tr>
<td>Evening session (Group curriculum sharing)</td>
<td>4.00</td>
<td>5.00</td>
<td>4.30</td>
<td>0.48</td>
</tr>
<tr>
<td>Informal Friday lunches</td>
<td>4.00</td>
<td>5.00</td>
<td>4.60</td>
<td>0.52</td>
</tr>
<tr>
<td>Curriculum writing</td>
<td>3.00</td>
<td>5.00</td>
<td>4.20</td>
<td>0.63</td>
</tr>
<tr>
<td>Informal conversations with peers</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Individual curriculum meetings with coordinator</td>
<td>3.00</td>
<td>5.00</td>
<td>4.60</td>
<td>0.70</td>
</tr>
<tr>
<td>Presentation of designed unit</td>
<td>4.00</td>
<td>5.00</td>
<td>4.70</td>
<td>0.48</td>
</tr>
</tbody>
</table>

N = 10
<table>
<thead>
<tr>
<th>Component</th>
<th>Example comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory experience</td>
<td>Good content, nice people, but no hands on Greatest lab learning experience I've had in a long time.</td>
</tr>
<tr>
<td>Evening sessions (design)</td>
<td>Okay but theoretical not skills based It was good to experience peer ideas and to revisit the idea of backwards teaching.</td>
</tr>
<tr>
<td>Former intern</td>
<td>She was very nice but did not have any impact on my learning or lesson. Ability to bounce ideas off others who have had similar experiences.</td>
</tr>
<tr>
<td>Curriculum writing</td>
<td>Intense! But a great learning experience. Long, but a good skill developer for teachers. Allowed me to think out of the box.</td>
</tr>
<tr>
<td>Individual curriculum meetings with coordinator</td>
<td>Added guidance and assisted with more strategies. Awesome collaboration. Able to help with ideas.</td>
</tr>
<tr>
<td>Evening session (Group curriculum sharing)</td>
<td>Good to get feedback. Helped with other ideas. Good work ethic among teachers with positive and effective feedback.</td>
</tr>
<tr>
<td>Informal Friday lunches</td>
<td>It was a welcomed break but was not always easy to attend given what was taking place in the lab. A time to meet with those working in different labs.</td>
</tr>
<tr>
<td>Presentation of designed unit</td>
<td>A little long but nice to see what everyone did with their lab experiences. Good venue to see if you are on track to hit your design goals.</td>
</tr>
<tr>
<td>Daily reflection</td>
<td>Good but redundant. The daily reflection helped me to process my experiences of the day and kept me focused on the goal of the program.</td>
</tr>
<tr>
<td>Informal conversations with peers</td>
<td>Super! Peers share your views and know very well your struggles. They contribute the most to the whole curriculum development. Encouragement, ideas, new approach to design/delivery. Invaluable.</td>
</tr>
</tbody>
</table>

N = 10. Example comments are direct quotes.
CHAPTER 5
DISCUSSION

Overview

Teachers are tasked with designing educational learning experiences for their students and are expected to translate professional development experiences into classroom practice. However, there is little research on how and to what extent teachers engage in the process of design, particularly in the context of translating teacher-scientist partnership professional development (TSP PD) programs into learning experiences for the K-12 science classroom. This single case study of an existing TSP PD program aimed to understand the activity structures and design supports that foster science teachers’ ability to design learning experiences for their classroom context and how their design expertise relates to other forms of teacher knowledge such as subject matter knowledge and pedagogical content knowledge.

To frame the inquiry, conjecture mapping provided a hypothesis of how learning may occur in this particular TSP PD environment and the interaction of the variables under investigation. The high-level conjecture posited that developing science teachers’ design expertise through a TSP PD program requires providing varied activity structures that support first person authentic science learning (e.g. conversations with researchers, immersion in active research laboratories) and purposeful design support activities in order to enhance teachers’ professional knowledge (subject matter knowledge, pedagogical content knowledge, curriculum design knowledge) and skills for translating the experience into a designed lesson specific to the education goals for their classroom context.
The conceptual framework considered design expertise as the integration of a complex set of knowledge and skills, specifically subject matter knowledge (SMK), pedagogical content knowledge (PCK), and curriculum design knowledge (CDK). This study sought to understand the complex interactions of the designed intervention (TSP PD program) and outcomes (development of design expertise) in an authentic learning context. As such, design-based research (DBR) as a form of inquiry was utilized based on empirical research and theoretical considerations of the designed setting and its influence on learning. The following research questions drove the investigation:

- RQ1: How do the activity structures and design supports of the TSP PD influence subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge?
- RQ2: How do changes in subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge relate to the development of design expertise?
- RQ3: How do participants perceive the activity structures and design supports of a teacher-scientist partnership professional development program affording or constraining their design expertise?

Qualitative methods with inference testing were used during the investigation of this single case. Objective instruments were used as a repeated measure of SMK, PCK, and CDK. A previously published rubric was used to score the final designed products as a measure of design expertise. Additional data sources included participant daily reflective journals composed of both Likert-type scale items and reflective prompts, semi-structured interviews conducted with each participant during the final week of the program, and a storyline reflective method used as a summative measure of participants’ perceptions of the TSP PD program.

During data analysis, the objective measures revealed no gains in SMK or PCK attributable to the TSP PD program. There was an overall medium gain in CDK, and an
item analysis showed medium to large gains for most of the design elements described on the survey of CDK. Additional analysis of the subjective data through content analysis of the reflective journals revealed the participants believed their learning, pedagogical practices, and instructional design decisions were positively affected by the TSP PD program. All participants achieved a successful or highly successful level of design expertise based on the scores obtained using the Science Lesson Plan Analysis Instrument (SLPAI) to assess the final designed curricula. Each of the 22 SLPAI criteria was aligned to a knowledge type (SMK, PCK, CDK), which demonstrated each form of professional knowledge contributed to the measure of design expertise. However, while all forms of professional knowledge are important for design expertise, the singular gain observed in CDK suggests curriculum design knowledge was the primary form of knowledge needed for design expertise in this case.

The participants indicated all of the activity structures and design supports were both affordances and constraints to the development of their designed curricula. Participants in research laboratories with hands-on opportunities to engage in experiments reported more instances of affordance than those that lacked opportunities to develop laboratory skills and techniques. The curricular template used was an affordance for some who appreciated having a model to develop their lessons but a constraint for others who were limited by the format, which was not coherent with their school and/or district requirements. Lastly, all participants perceived collective participation as an affordance to their curriculum development. The findings suggest additional avenues of research to better understand how to support teachers as designers in TSP PD programs.
A discussion of the research findings is presented in the sections below. First, the findings for each of the three research questions are discussed in turn with suggestions for future iterations of DBR as they pertain to each question. Implications for science education research are presented along with recommendations for stakeholders of teacher-scientist partnership programs. The chapter concludes with a discussion of the conceptual framework followed by limitations and suggestions for future research endeavors.

**Influence of the TSP PD Program on Teacher Professional Knowledge**

Question one set out to understand what influence the TSP PD program had on the participants’ professional knowledge (SMK, PCK, CDK). This question was based upon the design conjecture that links the embodiments (e.g., activity structures, design supports, first person engagement with authentic science) with the mediating processes (e.g., observable interactions and artifacts of professional knowledge). The objective data sources show the TSP PD program influenced CDK but did not change SMK or PCK. However, subjective data revealed changes in all three knowledge types.

Data from the reflective journals showed the participants believed the program impacted their learning, pedagogical practices, and instructional design decisions. Likert-type scale ratings and comments indicated that participants believed the TSP PD program did positively influence their professional knowledge. The minimal quantitative change in SMK or PCK in contrast with the participants’ self-reported perceptions of their changes in professional knowledge illuminates difficulties observed in other studies utilizing objective and subjective measures where teachers may interpret the question incorrectly, possess knowledge of reform-oriented science that biases their response,
overestimate their knowledge or skills, or respond with social desirability bias (Jacobs et al., 2008; Smith et al., 2014).

Comparison to Pilot Study

The findings in this study regarding professional knowledge were similar to those of the pilot test with a similar group of participants during a two-week biomedical science-focused summer institute in June 2016. During the pilot test with 18 participants, the average gain on SMK was 1.33 points with a pre-assessment mean of 12.89 and a post-assessment mean of 14.22 on the multiple choice items. These scores were higher than for the current study (Pretest: $M = 12.09$; Posttest: $M = 12.63$). It is not surprising that the pilot teachers' subject matter knowledge improved since the assessment was aligned with the content of that TSP PD program including items involving protein synthesis, stem cell biology, and the cell cycle and cancer biology. Wayne and colleagues (2008) describe this situation well by comparing two studies that both measure content knowledge gains of teachers as a result of professional development and the students they subsequently instruct: a proximal measure that is designed based upon the specific content of the PD and the classroom intervention will necessarily show larger gains and suggest a larger effect than a more distal measure that is not designed purposefully to align with the PD and/or intervention. Similarly, PCK improved because there was explicit instruction and multiple activities included during the two-week institute with the pilot teachers. The pilot teachers included these newly acquired resources and pedagogical practices in the post-program administration.

The measure of CDK reveals interesting findings with the pilot group and study group performing similarly: pretest score was lower than posttest score and retrospective was the lowest of all (Pilot Pretest: $M = 76$, Retrospective: $M = 72.75$,

162
Post: $M = 83$; Current study Pretest: $M = 78.27$, Retrospective: $M = 73.81$, Post: $M = 84.64$). The activity structures and design supports utilized in the TSP PD program for the pilot group were informed by previous cycles of DBR of CPET’s TSP PD programs and provided the foundation for the cycle of DBR in the current study. The same activity structures and design supports are in place, however the participants in the current study engaged in additional consideration of how to design educative materials during evening sessions and used an extensive curricular model that is a self-contained unit. Even though the participants in this study engaged in more intensive design supports, there is little difference in the extent of agreement with attending to the 15 design elements between the pilot study group and the current study participants, suggesting the additional supports for the current study are not needed to improve curriculum design knowledge. Further research is needed to determine what features of the TSP PD are most important in developing curriculum design knowledge and longitudinal research to determine if changes in CDK are enduring and transferable to other professional learning experiences.

In the current study, two interrelated issues are considered as they impacted the measures of professional knowledge: the authentic setting of the research laboratories and the instruments used in this TSP PD program.

**Authentic Research Setting**

Drawing from the literature, placement in an authentic research setting was considered an important step toward improving teacher professional knowledge (c.f. Brown & Melear, 2007; Buck, 2003; Dresner & Worley, 2006; NRC, 1996, Schwartz, Lederman, & Crawford, 2004) and that through a cognitive apprenticeship (Brown, Collins, & Duguid, 1989), teachers would gain knowledge of authentic science practices
and deeper content knowledge. TSP PD programs and placement of teachers in authentic laboratory settings is advocated as a mechanism to increase SMK and PCK, particularly as an approach to deepen teachers’ understanding the nature of science and inquiry practices (Blanchard, Southerland, & Granger, 2009; Miranda & Damico, 2013; NRC, 1996). Accordingly, the TSP PD program in this study placed participants in authentic, naturalistic research settings without a defined curriculum. However, much of the argument for increasing SMK and PCK comes from the consensus model of professional development described by Desimone (2009) and is further supported by teachers’ self-reports. Indeed, the hallmark study by Garet and colleagues (2001) is based upon teachers’ self-reports of knowledge changes and important features of professional development.

It is difficult to show learning gains or large effects if the assessment measures are not tightly aligned with the intervention. If the laboratory experience becomes too scripted, the authentic nature of scientific inquiry is lost. In the current study, the participants did not gain SMK or PCK based on the objective measures. However, the daily descriptions of their laboratory experience indicate they believe it was a positive experience that influenced their professional knowledge. There appears to be a benefit of teachers engaging in authentic laboratory experiences, but quantifiable gains were not measurable in this study. Further research is needed to better understand what professional knowledge is gained through an authentic research experience and how this is translated into practice. Future iterations of DBR with TSP PD programs should identify or develop other measures of SMK and PCK that are valid and reliable yet
usable in diverse laboratory settings to ascertain the knowledge gained regardless of the content focus of the laboratory. The instruments used are discussed next.

**Study Instruments**

The instrument utilized to assess SMK was developed as a measure of broad understandings of biomedical science. A review of the literature did not identify an assessment that would be an approximate indicator of subject matter knowledge for high school life science teachers; therefore, an instrument developed for a CPET two-week biomedical-focused TSP PD was believed to be the closest available measure.

Participant 6 pointedly commented on the post administration “I did not learn this here but knew it already” (P6, BKA post). This comment suggests there was a problem with the design of the program and the measure. The SMK learning model employed in this TSP PD program is largely unstructured and based upon exposure, similar to the incidental learning that may occur in informal education environments. The participants were not in explicit learning situations where they were required to engage in learning strategies nor were there structured mechanisms to check for understanding. This has implications for TSP PD programs of how to structure the program with appropriate learning situations that generate SMK gains while maintaining the authentic research experience. There are no reports of TSP PD programs that place teachers in authentic research laboratories as the exclusive means of deepening content knowledge that provide evidence of statistically significant changes in SMK using objective measures. Interestingly, a review of authentic research experiences revealed only 11 manuscripts or reports of authentic experiences for teachers and the five that reported changes in content knowledge were based on self-report surveys or interviews (Sadler, Burgin, McKinney, & Ponjuan, 2010). Some studies exist that consider environmental and field-
based TSP PD programs in which teachers self-report an increase in SMK such as the Teacher in the Woods program (Dresner & Worley, 2006) or use a previously validated instrument to measure changes in middle school teachers understanding of geology and ecology of Yellowstone National Park (Houseal, 2010; Houseal et al., 2014). Importantly though, the context and design of these TSP PD programs is different from the current study. For example, Houseal (2010) designed her PD to prepare teachers to bring their students on an extended visit to the park. The content was aligned with state standards and the curriculum provided for all of the teachers was uniform, supporting content knowledge for teaching (Ball, Thames, & Phelps, 2008). As suggested above, if the goal of the TSP PD program is to increase SMK as a quantifiable outcome, much work is needed to develop an appropriate instrument that corresponds to learning activities that promote deeper conceptual understanding. Due to the variability of the laboratory placements and the small sample size of participants, it would be a challenge to propose a research design that supports a generalizable effect. Instead, future research should focus on what knowledge types are impacted by TSP PD programs.

It may be that TSP PD programs are not the appropriate form of PD if the goal is increasing SMK that aligns to standardized tests and state benchmarks. After a large-scale study of NSF funded Local Systemic Change through Teacher Enhancement Initiative PD programs, Banilower and colleagues (2007) suggest “researchers need to recognize approaches may be effective for some goals, but not for others (e.g., a workshop may be an effective and efficient method for deepening teachers content knowledge, but study groups may be a better choice for helping teachers understand how students think about specific science concepts)” p. 391.
The study participants believe their learning, pedagogical practices, and instructional design decisions were influenced by the TSP PD program. This suggests that for at least self-report measures, perhaps engaging experienced teachers in the process of design influences other forms of knowledge. Participant perceptions of increased professional knowledge relates to their professional identity and their concept of self. Knowles (1992) argued that a teacher's concept of self determines the way they teach, their development and evolution as a teacher, and their attitude towards educational changes. In future iterations of DBR for this TSP PD program, increased emphasis should be placed on developing CDK through additional design supports such as increasing the number of dedicated group and individual work sessions for feedback and sharing of progress. All stakeholders should be involved in this: participants share and support each other; CPET staff offers guidance and constructive feedback; and scientists check for understanding as teachers update their mentors on their progress.

To attend to increasing SMK that can be measured, future TSP PD programs could include content learning sessions such as a morning lecture series or opportunities for participants to rotate through different research laboratories. These topics could then inform the SMK instrument and the assessment could measure impacts on professional knowledge based on those shared learning experiences. However, inclusion of these experiences necessarily calls for a reduction in the number of hours in the research laboratory and also returns to the question of what the role of the authentic research setting is in developing professional knowledge. Depending on the aims of the TSP PD program, the immersive experience may be a priority to objectively measuring SMK or PCK. In this study, this was the case.
How Professional Knowledge Relates to Design Expertise

Question two considers the main construct of this study: design expertise. Design expertise is operationalized in this study as the integration of subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge. The theoretical conjecture informed question two as it connects the mediating processes (e.g., observable interactions and artifacts of professional knowledge) with the resulting outcomes of the design intervention (e.g., design artifact that translates the TSP PD into a classroom learning episode). It is this conjecture that hypothesized how professional knowledge (SMK, PCK, CDK) relates to design expertise for the TSP PD program participants. Using the Science Lesson Plan Analysis Instrument to evaluate the final designed curricula, each participant’s SLPAI score was taken as a measure of success with higher scores equating with higher levels of design expertise. All participants were successful with the curriculum design task and demonstrate a medium to high level of design expertise. This indicates that the TSP PD program facilitated the participants’ design expertise.

As previously indicated, there were quantitative gains in CDK but not in SMK or PCK. These findings indicate that of the forms of professional knowledge, CDK most influenced design expertise. The TSP PD program introduced the participants to design principles and was planned with a defined set of activity structures and design supports available to all of the participants to scaffold their curriculum writing experience. CDK received concentrated and consistent focus during the three weeks which may have influenced the gains seen in this form of professional knowledge compared to SMK and PCK and consequently the success of all participants in demonstrating success with the curriculum design task.
The amount of structured program time related to each of the knowledge types may have a direct relationship to the gains observed (CDK) as well as lack thereof (SMK, PCK). Though the participants spent a considerable amount of time in the research labs (~60 hours) and were asked to reflect on their learning each day as well as maintain a laboratory notebook, the laboratory experience was not designed as a structured learning experience employing specific learning strategies or a mechanism to check for understanding. This could explain the minimal gains in SMK. Similarly, there was no structure within the TSP PD program that would allow participants to specifically build their PCK. For both SMK and PCK, participants were expected to deepen their knowledge but not provided explicit support to do so within the TSP PD program. Conversely, the TSP PD program included considerable structure and several activities specifically focused on developing the participants’ design knowledge and as a result, gains were observed. These findings show that without specific structure within the TSP PD program, the learning intervention is based upon passive exposure, so learning gains will be minimal and inconsistent. These findings are similar to incidental learning that occurs in informal settings. As the learning becomes more structured, it aligns with the model of formal education. This also indicates that if TSP PD has PCK as a goal, then it needs to include specific and explicit support of pedagogical practices.

Each form of professional knowledge contributes to design expertise, which in this study is focused on participants translating their laboratory experience into a learning episode for their classroom. The participants display both SMK and PCK in their designed curriculum as indicated by the scores on the individual SLPAI criteria and their scores and comments from their reflective journals. The SMK and PCK displayed
in the designed curriculum are specific to their unique laboratory experience combined with their personal resources whereas CDK itself is informed by the field of instructional design and is the knowledge and skills needed to logically and orderly design a learning experience. It is a set of knowledge and skills that are transferable to any discipline while SMK and PCK are topic and discipline specific. They are needed, but they are developed within a single subject area and vary for the topics within a subject (Gardner & Gess-Newsome, 2011). As such, measures of CDK are likely to be applicable to multiple PD programs that incorporate explicit design support. In facilitating the development of design expertise, TSP PD programs are best served by fostering participants’ development of CDK and providing the activity structures and design supports that enable them to practice their CDK through the translation of a laboratory research experience into a classroom learning episode. Future research should consider revising the SLPAI to align with multiple dimensions within SMK, PCK, and CDK, to provide a more accurate measure of the depth of professional knowledge presented in a designed curriculum. This would situate all of the knowledge types within the same context to generate a measure of design expertise specific to a topic.

Participant Perceptions

The final research question considered the participants’ perceptions of how the activity structures and design supports afforded or constrained their developing design expertise. This question aimed to understand the range of experiences within a single TSP PD program from the participants’ perspectives. Through the use of semi-structured interviews with each participant and the storyline approach, participants shared that the activity structures and design supports previously identified from the literature were both affordances and constraints to their work translating their laboratory
experience into a curricular module. There were some structures and supports (laboratory experience, curricular template, collective participation) that garnered a great deal of feedback and therefore conveyed more importance to the participants in the current study. These are discussed further below.

**Laboratory Experience**

The placement in an authentic research laboratory was the primary reason participants cited for attending the TSP PD program in this study. The laboratory experience provided content for the participants to build their curriculum which was viewed as an affordance; however, for those that did not have many opportunities for hands-on laboratory skill development or could not place the specific focus of the lab into a broader view of the subject, the research experience constrained their curriculum design. The importance the participants place on using authentic research equipment and developing laboratory skills may be related to their focus on experiments in the classroom. Participant 4 felt a good science teacher should engage students in laboratory experiments at least once a week (P4, Interview) while Participant 2 shared that the curricular template and model curriculum included too many activities that were not "real science" because they were not laboratory experiments (P2, Interview). Ironically, while the participants sought this engagement, some commented about the inaccessibility of the laboratory procedures in their classroom and lack of transferability to the classroom. To address this situation in future programming, CPET and the research laboratories need to provide additional support to the participants to help them modify procedures and focus on incorporating techniques only if they enrich the students’ learning experience in a meaningful manner to promote deep understanding. The participants’ comments also suggest further research is needed regarding what
purpose engaging teachers in laboratory techniques serves and how exploring a narrow topic in depth in a basic science lab contributes to a teacher’s broader understanding of the content area. These constructs should be pursued in future research to understand to what extent engagement in different forms of theoretical and practical research influence teacher professional knowledge and practice. Previous work of others using both objective measures and self-report indicates authentic laboratory experiences do influence inquiry teaching and conceptions of nature of science; however, there are also studies that indicate teachers have difficulties in translating these practices in the classroom (Blanchard et al., 2009; Miranda & Damico, 2013; Miranda & Damico, 2015).

**Curricular Template**

Previous TSP PD programs offered by CPET have used different templates for lesson development or allowed teachers to use a format of their choice. The resulting products from these programs offer little in the way of consistency or a design model reflective of a single TSP PD program. They are minimal, specific to the teacher that created each, and difficult for other educators to utilize. Allowing participants to use a format of their choice addresses the issue of coherence, however it does not serve the wider audience of a federally funded program such as the TSP PD program that is the focus of this study. The aim of the current TSP PD program was to introduce the participants to designing educative curricular materials that translate their experience in the research laboratory to a classroom module. To scaffold their curriculum writing, a curricular template was provided for the participants to use. This design support was found to be beneficial by other studies (Huizinga et al., 2015; Penuel et al., 2011). For the participants who shared they understood the purpose of the template and the role of educative materials in supporting their curriculum writing (Ball & Cohen, 1996; Penuel et
al., 2011), they expressed the curricular template as an affordance. For those that resisted using a different format than they were accustomed or did not understand the goal of the program to create educative materials, the template was viewed as a constraint. Future TSP PD program design should include more time devoted to exploring educative materials, examining additional exemplar materials, and having additional group design sessions to facilitate understanding so that the curricular template can be viewed as an affordance for all and be coherent with their personal views.

**Collective Participation**

With the exception of the comments from one laboratory pair (P8 and P9), all other comments demonstrated that Collective Participation in the form of interactions with peers as being an affordance to the participants’ curriculum development. The social aspects of the TSP PD program and the ability to share with like-minded individuals are strong positive attributes of a TSP PD program that should be maintained. Even though one pairing was not as successful, each participant shared positive comments regarding others with whom they could interact and gain the collective participation that is a feature of high quality professional development. Similar to findings by Desimone (2003), the participants shared feelings of isolation in their classroom and school that were contrary to their experiences at the TSP PD program. They also spoke of continuing relationships beyond the program and sharing resources during the school year consistent with previous findings by Dresner and Worley (2006). This activity structure should remain in all future TSP PD iterations. Importantly, the participants found both pairings and whole group interactions to be affordances suggesting TSP PD programs should be designed to include multiple teachers. There is
no cohort size suggested in the literature, and the current study selected 11 participants based on previous iterations of DBR. The NSF now requires a minimum cohort of 10 teachers for RET sites, perhaps acknowledging that a critical mass of teachers is an affordance of the program, but also supports individual RETs as broader impacts with only one or two teachers participating which does not promote collective participation.

**Conceptual Framework Revisited**

This study set out with a conceptual framework of design expertise modeled after Huizinga’s (2014) work that suggested a view of subject matter knowledge, pedagogical content knowledge, and curriculum design knowledge as being separate boxes of knowledge at the same hierarchical level that together in equal parts illuminate design expertise at a higher level (Figure 2-2). Additional literature suggested a hierarchy to the forms of professional knowledge with SMK as the most important followed by PCK. Indeed, Shulman (1987) describes pedagogical reasoning as the process that all teachers undertake as they craft instructional episodes for their classroom, similar to design expertise in this study. The first step in this process is for the teacher to comprehend new content and knowledge personally and then transform that knowledge into a manner and level suitable for the students. All of the participants in this study demonstrated a successful level of design expertise although the SMK and PCK measures indicated no change in these forms of knowledge. Even if we do not consider change attributable to the TSP PD program and consider a baseline SMK and PCK for the participants, the range was wide across the participants in this study, yet all were able to successfully design a novel curriculum. In fact, if we were to consider individuals, Participants 5 and 6 had the highest SMK scores and the lowest SLPAI scores indicating that high SMK does not necessarily translate into high design
expertise. These findings suggest a different model of the development of design expertise than that proposed by Huizinga (2014) which formed the conceptual framework for this study. The research on teachers as designers of educative science curricula is quite limited and the relationship between the forms of professional knowledge has not been explored. However, one study of a related construct, pedagogical design capacity, suggests an alternative framework that can be used to consider the relationship between professional knowledge and design expertise.

Brown's (2002) work with pedagogical design capacity suggests that how a teacher implements educative materials is dependent on personal (SMK, PCK, goals and beliefs) and curricular resources. In his framework, personal resources are presented as linked constructs in a circular fashion without directional arrows, placing equal emphasis on all parts and together they combine with curricular resources to result in an instructional episode based on educative materials. In this investigation, teachers created novel materials that translated an authentic research experience into classroom practice rather than adapting something already prepared. Therefore, there was not a common factor such as the implementation of the same educative curriculum to compare what and how teachers called upon different resources including different types of professional knowledge. However, professional knowledge is varied, yet all of the teachers were successful designing a curricular module. This suggests there is an interaction among the knowledge types that taken together contribute to design expertise as shown in Figure 5-1. This study demonstrated CDK is a necessary factor contributing to design expertise. CDK embodies the skills needed to purposefully and logically design a learning experience. SMK and PCK are needed, but these knowledge
types are drawn upon to develop the learning experience once the design is in place. CDK provides the foundation or the scaffolding for the final designed product while the SMK and PCK provide the content and instructional approach for implementation. This is why design expertise is critical and why teachers should be considered designers: they can possess the knowledge and opportunity to design an instructional episode taking on the role of an instructional designer and to develop and deliver an instructional episode as a professional educator for their specific classroom context.

SMK and PCK were not explicitly addressed within the program design of the current TSP PD and depended on passive transmission of knowledge. Accordingly, there were no observable changes in these knowledge types, yet the participants were able to draw upon the SMK and PCK they did possess, either before or as a result of their immersion in the authentic research setting, to successfully develop a final designed product as outlined by their CDK. Huizinga (2014) considered SMK and PCK as necessary components of design expertise, but found in his study that the main support needed for teacher design teams was CDK as they drew on their exiting SMK and PCK. At different points in their careers and considering different topics, SMK, PCK, and CDK vary and contribute differently to design expertise. Similarly, as Brown (2002) demonstrated, personal, contextual, and curricular resources influence how teachers utilize different forms of professional knowledge as they design new learning episodes. This study did not explore personal or contextual factors such as the six factors that Hong (2010) described in his study of professional identity: value, efficacy, commitment, emotion, knowledge and beliefs, and micropolitics. This opens an interesting avenue for future research to consider outcomes of professional development that focus on the
person and specifically, consider the impact TSP PD programs may have on teachers’ professional identity. The implicit and consensus models of PD and indeed the theory of action for this current study focus on changing teacher knowledge, beliefs, and/or practices related to teaching with the intent of these changes positively influencing student learning. TSP PD programs do not seem to be effective PD outlets for altering SMK or PCK in a large, generalizable fashion as evidenced by the inconsistent outcomes reported in the literature based largely on teachers self-reporting knowledge gains. However, they may be effective for positively impacting professional identity and retention in the education profession. These ideas are explored next.

**Implications for Science Education Research**

Considering professional development, the No Child Left Behind act calls for professional development to be high quality (115 STAT. 1698, NCLB, 2002). These programs are “characterized by coherence, active learning, sufficient duration, collective participation, a focus on content knowledge, and a reform rather than traditional approach” (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). According to the guidelines provided, high quality PD should have all of these features that implies they should all be measurable and yield significant results. However, even though there are numerous studies of professional development, relatively few employ methodologies consistent with What Works Clearing House evidence standards to allow generalizations to be drawn (Desimone, 2009; Yoon et al., 2007) but rather are based on self-reports, small sample sizes, incomplete data, or do not utilize rigorous design methods. The current study is no different. It is a single case study of an existing TSP PD program with 11 participants. It does not have the statistical power or research design needed to make claims of effectiveness, particularly regarding changes to teacher practice. What it does
bring to light is the extreme contextual basis for every professional learning experience and the necessity to align the design and goals of the PD with the outcome measures. TSP PD programs such as the one in this study cannot be reduced to a prescriptive experience. They are unique and bring the teacher into the authentic, messy environment of a working research laboratory immersing them in the process and product of science from a first person perspective. Based on the participants in this study, the elements of high quality professional development were present and afforded their curriculum development. However, if successful PD is based on increases in objective measures as many PD programs strive to accomplish, the TSP PD program in this study was not wholly successful although the participants in the current study perceived their TSP PD experience as being “the best professional development I’ve ever done” (P2, Interview).

Another factor to consider is the frustration and demoralization the participants expressed they experience during the school year. While on the university campus, they are treated as professionals who are knowledgeable and valued for the unique skills and perspectives they bring to the learning environment. Previous work by Bokor and Crippen (2016) demonstrated that teachers return to TSP PD programs run by a single center for these reasons. They feel appreciated and part of a community of practice where they are comfortable and surrounded by like-minded colleagues. The current study and the previous work call for additional research into the role of TSP PD programs as retention programs for science teachers. Luft and colleagues (2003) describe the evolution of the science teacher.
The process begins with preservice education, continues through the induction years, advances to the early and mid-career stage, and culminates in the master teacher or late career phase. Given this understanding of teacher development, science teacher educators have varied their curriculum and instruction to foster the evolving science teacher. (p. 3)

There is a growing body of research and corresponding programs aimed at the early years of teaching to retain beginning teachers in the teaching profession by offering targeted support for science instruction and practices as they build their professional knowledge (i.e., Crawford, 2007; Davis, Petish, Smithey, 2006; Luft, Roehrig, & Patterson, 2003). TSP PD programs of extended duration such as the three-week program in this study or the longer seven and eight-week programs common with NSF funded RET programs target experienced teachers who are further along in their profession and personal lives. These are also teachers that tend to be comfortable with their current position and are confident in their teaching. Among the 11 participants in this study, they are department chairs, district coaches, long-time AP and IB readers, and close personal friends with their administrators. Yet despite these personal and professional securities, they seek PD opportunities such as TSP PD programs. Their comments reveal they do this to reaffirm their professional identity which is “a dynamic, continually changing, and active process which develops over time through interaction with others…continually being formed and reformed through the way (they) internalize the external environment, negotiate interactions, and externalize (themselves) to others” (Hong, 2010, p.1531). A teacher’s professional identity is defined in various ways by different researchers. This study adopts the perspective that “teachers derive their professional identity from (mostly combinations of) the ways they see themselves as subject matter experts, pedagogical experts, and didactical experts” (Beijaard, Verloop,
Additionally, there is a relational aspect to professional identity that has implications for TSP PD programs. Teachers are part of an education community of practice (COP) in their daily professional lives and as such their professional identity is developed and maintained due to the social interactions and negotiation of roles in that particular context (Beijaard et al., 2000). Participating in a TSP alters the COP in a manner that places the teacher outside the K-12 community and allows them to participate in a COP of science research. As professional identity is shaped by interactions, future research should consider how TSP PD programs then influence teacher professional identity within the K-12 COP. Most commented that they engage in PD activities in search of resources they can take back to their students. In some cases, those resources might be activities they can plug and play or it might just be a spark to excite them about teaching again and restore their confidence that they can make a difference in the lives of their students. Participant 3 discussed her excitement with her newly designed curriculum and the value she placed on the TSP PD program for supporting her professional identity.

I can’t wait to bring it in to my class and to feel excited about being in the classroom again even if it’s for a little unit. I think it will help so much just to recharge them and validate them as teachers and we don’t get that. I think that’s one of the very important parts of the way that this program is designed and how it is run as the other ones are is that we are from day one treated as teachers but with respect and validating us for what we do and that it’s worthwhile. That helps a lot. (P3, Interview)

Enthusiasm, excitement, and passion are needed for personal and professional satisfaction. In education, this can translate to retaining quality classroom teachers to engage our next generation of learners in the wonder of science. Participant 4’s advice for future TSP PD participants reflects the importance of “professional renewal” (Dresner & Worley, 2006, p. 12):
Enjoy yourself, take in the lab experience, and just reflect on yourself as a professional. Take in the experience, reflect on it, and go into the year refreshed and be a better science teacher. (P4, Interview).

Further research is needed to understand how TSP PD programs relate to retention and how this particular form of PD is situated in the career of an educator knowing that professional development needs change over the course of a teacher’s career as the science teacher continues to evolve.

**Recommendations for Stakeholders of Teacher-Scientist Partnership Programs**

This study was bounded by the three-week on-campus component of an existing TSP PD program and therefore recommendations are limited. They are also based on a TSP PD program that has the infrastructure of an outreach center to provide coordination and continued classroom support. A TSP PD program is a large investment of time and money on the part of all partners. To maximize the on-campus component, pre-program information should be provided in advance. In this study, the participants were not made aware of their laboratory placements nor were they provided any advanced readings because of the concern that this would skew results and increase incoming knowledge. However, the first week of the program in particular seemed to present a large demand on the participants as they were not only learning new content and laboratory skills, but also acclimating to the laboratory setting and on-campus living. The additional evening sessions were productive, but the readings could have been sent in advance so they had more time to consider them and reflect prior to and after group discussions.

The teachers in this TSP PD program were only in the laboratory for two weeks. This was made very clear in the communications before and during the program so was not an issue for the teachers in this study. All participants felt this was ample time.
However, it is not enough time for the teachers to engage in independent research projects, which could be a problem for the host laboratory. For example, one potential lab host that was approached politely declined because he did not feel it was long enough to provide a mutually beneficial experience for both partners. It is also not aligned with NSF’s current RET model which may influence the funding potential of future programs of this duration.

An element not included in this program was adequate time for review and feedback on the developing curricula. While there was to be another person working with the teachers, other CPET programs left me as the primary coordinator for the eleven teachers. There were simply not enough hours. Having the participants take on a critical friends role and provide peer review during the process, which provides additional scaffolding and engages the participants themselves in a social constructivist manner, could help this. This would also provide another opportunity to promote sound pedagogical practices and build collegiality.

Encouraging more participation from the laboratory hosts to assist with the development of the curricula would be beneficial to both partners to bridge the cultural differences between a research laboratory and science classroom (Houseal, 2010; Tanner et al., 2003). A TSP is a social interaction that creates meaningful learning between scientists and teachers within a zone of proximal development (Vygotsky, 1978) as more knowledgeable individuals (scientists) assist the developing understanding of learners (teachers) to create meaning that increases scientific literacy and engagement with science. Equally important, the teacher facilitates the researcher’s understanding of how to communicate science to different audiences thereby refining
the researcher’s perspective about teaching and learning. Within TSPs, both scientists and teachers fill the roles of expert and novice through mutual learning. The faculty may not be able to assist with the pedagogical practices or the instructional design, but they can clarify SMK and associated laboratory skills, ensuring the science content is represented accurately and sequenced appropriately, particularly as an extension and broader impact of the research laboratory.

Lastly, the nature of the relationship between teachers and scientists should be considered. This study did not address this aspect beyond ensuring that the principal investigator (PI) of the laboratory agreed to host a teacher-pair and checking in with the placements to make sure all parties were content. In all cases, the PI was not the direct mentor of the teacher-pair, but rather assigned a graduate student or laboratory staff to this task. Most of these individuals were excellent choices and provided support for their teacher-pair not just during the first two weeks of their laboratory placement, but also during the third week to answer additional questions and discuss their curricula. Some even attended the final presentations. However, there was no training or guidance provided to these individuals who in some cases found themselves as mentors very near to the arrival of the teacher-pair. The partnership can perhaps be more fruitful if the scientists providing the direct mentoring are more vested in the TSP PD program and provided opportunities to prepare for their role.

**Limitations**

As with all studies, there are limitations. The main limitations within the current study were related to the instruments. Both the SMK and PCK assessments required participants to provide detailed responses that would facilitate scoring using the AP Biology scoring guidelines and the PRIME PCK rubric. The participants did provide
more complete answers to the FRQ on the BKA relative to the amount of information provided on the PRIME PCK reflection prompt, however the brevity on both limited scoring. Gardner and Gess-Newsome (2011) also report limited responses on the PCK reflection prompt and attempted to encourage teachers to answer more completely on subsequent administrations with limited success. One limitation their study participants cited was the lack of feedback on the reflective prompt so they did not put much value in the exercise. Similarly, the participants in this study may not have understood the purpose or valued the reflective prompt as something to put effort into. However, another factor related to the brevity of the PCK responses is the infrequency teachers are asked to reflect on their practice (Gardner & Gess-Newsome, 2011). Indeed, Kirschner (2015) calls into question the ecology of teachers as designers that assumes an ideal state of teacher practice to include reflection. Kirschner is critical that teachers are not reflective practitioners. The participants in the current study confirm this notion. They reported rarely reflecting on an instructional episode, and if they did, it consisted of a sticky note on the hard copy of their lesson plan (P1, Field notes, Day Four).

In addition to the brevity of responses, the participants made few changes to their pre administration responses of SMK and PCK, which resulted in the minimal gains observed. The original responses were returned to the participants with the hopes that they would revise their responses by reflecting on what they originally wrote and also minimize the discomfort of completely rewriting their answer. However, the cognitive strain and anxiousness to return to their curriculum writing may have limited the time spent and thought given to constructing revised responses. Indeed, Participant 2 wrote the following on the FRQ: “I feel like I need to add more but cannot think of how to put
this together for more details. I am brain tired” (P2, BKA post). The general sense from the participants was mental exhaustion due to the task of designing their curriculum.

Another limitation of the SMK assessment in this particular program is the source of the questions. Fifteen of the 18 multiple-choice items are from the test bank of a popular advanced level biology textbook (Biology by Campbell & Reece) used by many AP Biology teachers. There are hundreds of questions in the test bank, so a participant likely will not remember a specific item, but they may be more familiar with the content and style of the items, which could provide an advantage to those individuals and limit gains in SMK. Relatedly, there may be a ceiling effect for this SMK assessment which limited the potential for content knowledge gains. For those participants who answered all or most of the items correctly on the pre-administration, there was not the opportunity for them to demonstrate increased knowledge on the post-administration.

A persistent limitation to TSP PD programs is the level of coherence between the program and the personal and contextual settings of the participants. In this study, the participants were experienced teachers who expressed some level of autonomy in their instructional design decisions. However, they all conveyed constraints encountered as each was preparing their students for standardized exams, either administered at the district, state, national, or international level. These constraints limit the autonomy of the participants and could have restricted their design expertise.

This study does not consider the perspective of the scientists or offer an view of the context of the research laboratories beyond the participants’ perceptions of their interactions and activities. Their reflective journals, informal conversations, and interviews reveal there was a wide range of experiences between and among the
participants that were dependent on the research laboratory. For those participants who
did not have the opportunity to engage in hands-on laboratory experiments, it may have
restricted their design expertise and resulting curriculum design. Similarly, those
participants with mentors who excelled at explaining procedures and engaging the
participants in active learning may have had an advantage designing a curriculum that
demonstrated higher levels of coherence with the criteria for design expertise. Variability
in the laboratory setting was not controlled for in this study and may have impacted the
results.

The small size and unique context of this study urges caution in making any
generalization. The small sample size limits the generalizability or transferability of the
findings. The length of the program introduces many contextually-related decisions that
may not be applicable to other settings (DBRC, 2003). Additionally, the study
participants applied and were selected to attend the TSP PD program that is the subject
of this study, so they are likely not representative of all teachers.

Conclusion

This chapter presented a discussion of the findings of the current study and
considered the findings in relation to future iterations of DBR and TSP PD programs.
The current study investigated how the activity structures and design supports of a TSP
PD program foster science teachers’ ability to design learning experiences for their
classroom context and how their design expertise relates to other forms of teacher
professional knowledge. The minimal gains in SMK and PCK and medium and large
gains in CDK present an interesting scenario for research that focuses on explicit
support of CDK for experienced teachers as they translate an authentic research
laboratory experience into a designed curriculum. It also suggests that TSP PD
programs may not be the appropriate form of PD to develop SMK and PCK if the design of the program is to immerse teachers in an authentic research setting without structured learning experiences. The TSP PD program in this study depended on incidental learning similar to an informal learning environment. This program design allowed the authenticity of the laboratory experience to be maintained which was a primary goal of the PD. All of the activity structures and design supports were viewed as affordances and therefore should be retained in future programs, with minor modifications to attend to the few constraints the participants shared. This study introduced a new conceptual framework that removes the hierarchy of knowledge types and suggests a direct and necessary relationship between CDK and design expertise. TSP PD programs should consider the impact these forms of professional learning may have on alternative constructs such as retention, professional identity, and designing next generation learning environments for K-12 classrooms and focus on the participants in the PD program and how best to attend to their personal and professional needs.
Figure 5-1. Conceptual framework of the professional knowledge types needed to develop design expertise in the context of this study’s TSP PD program
Lab 1  
P1 & P8  
Department of Biochemistry and Molecular Biology  
College of Medicine  
The focus of our laboratory is to analyze mechanisms regulating gene expression during erythroid cell differentiation. The beta-globin genes are regulated by a locus control region (LCR). The LCR is composed of several DNase I hypersensitive (HS) sites that together mediate chromatin structure alterations and high-level transcription throughout erythroid development. The human beta-globin gene locus consists of five genes that are expressed in a developmental stage specific manner in erythroid cells. During development the different proteins encoded by the beta-globin gene locus (ε, Aγ, Gγ, δ, and βglobin) dimerize with α-globin subunits to form hemoglobin. The beta-type globin genes are expressed at extremely high levels in erythroid cells which is mediated by the LCR.  
Results from our previous work suggest that the individual LCR HS elements interact to generate a higher order structure, referred to as the LCR holocomplex, and that this complex communicates in a stage-specific manner with individual globin genes. We also found that the LCR recruits transcription complexes and proposed that the LCR serves as the primary site of transcription complex recruitment and assembly in the beta-globin gene locus. We use transgenic mice and cell culture to identify and functionally characterize cis-regulatory DNA elements and trans-acting components involved in the regulation of the beta-globin genes. We utilize artificial DNA binding domains to modulate and characterize the function of transcription factor binding sites in the beta-globin gene locus. We also use a variety of molecular techniques, including chromatin immunoprecipitation (ChIP), ChIP-sequencing, shRNA mediated knockdown, and overexpression of dominant negative transcription factors to analyze transcription factor function and globin gene regulation.

Lab 2  
P3 & P11  
Department of Physiological Sciences  
College of Veterinary Medicine  
Copper and iron are vital nutrients with a highly conserved and interwoven metabolism that is required for the growth and development of all organisms. An overall research goal of the laboratory is to further understand copper and iron metabolism in mammals with a focus on 1) characterizing the role of the multi-copper ferroxidases (Fe (II)-> Fe(III) in iron homeostasis and 2) identifying the genetic factors that influence iron status in mammals using "in silico" QTL analysis of inbred mouse strains and collaborations to study genetic determinants of iron deficiency in zebrafish and humans. We are utilizing systematic functional analysis through the use of “barcoding” analysis in the budding yeast Saccharomyces cerevisiae to identify conserved toxicity pathways that may provide insight on toxicant susceptibility in people. We are currently focused on breast cancer carcinogens, mitochondrial toxicants, pesticides and
emerging contaminants. Most recently we have started using whole genome CRISPR approaches in a similar approach in mammalian cell lines.

We are developing a novel approach for identifying and understanding the toxicity of xenobiotics in aquatic ecosystems by monitoring changes in global gene expression patterns in aquatic indicator species representative of different trophic levels, including Daphnia magna (a crustacean), and *Pimephales promelas* (fathead minnow). We are assessing the sensitivity, specificity and utility of an ecotoxicogenomics approach for ecological toxicity assessment in real world environmental settings. Tools we are using include traditional microarray technologies as well as high-throughput sequencing methods.

Lab 3
P5 & P6
Department of Biochemistry and Molecular Biology
College of Medicine
Our research lab uses a broad range of approaches to study the molecular mechanisms of neurological diseases that are caused by microsatellite repeat expansions. For many of these diseases (myotonic dystrophy, ALS and ataxias), RNA processing (pre-mRNA splicing) pathways are negatively impacted with specific changes in pre-mRNA splicing proposed to lead to symptoms observed in affected individuals. We use biochemical, cellular and genomic assays to understand the mechanisms through which these diseases alter pre-mRNA splicing. The goal of our research is to use the results from these fundamental studies to identify innovative strategies to reduce or correct the improper pre-mRNA splicing that occurs in the disease state. For example, we have recently shown that small molecules can be used to rescue the mis-splicing in cell and mouse models of myotonic dystrophy.

Lab 4
P2
Department of Pathology, Immunology, and Laboratory Medicine
College of Medicine
The last 25 years have witnessed an unprecedented development of molecular evolution, phylogenetic and population genetic methods. On one hand, the advent of PCR technologies has allowed for the generation and rapid accumulation of nucleotide sequence data from many organisms including several eukaryotic species, bacteria, viruses and eventually the full human genome. On the other hand, the increase in computational speed of computer clusters, as well as desktop and laptop computers, has allowed for the implementation of sophisticated algorithms that would not have been computationally feasible just two decades ago.

The discovery of fast-evolving viruses, such as HIV and HCV, poses special challenges to evolutionary theory. The understanding of both inter- and intra-host evolution of these viruses is crucial and has broad applications ranging from molecular epidemiology to drug resistance, pathogenesis and forensics. Molecular evolution of pathogenic viruses includes experimental work to isolate and sequence viral strains from different hosts or from the same host over time, DNA and RNA sequencing techniques, as well as the development and application of phylogenetic and population genetic methods to gain
insights on the interplay between viral evolutionary patterns, origin and spread of epidemic outbreaks and pathogenesis.

More recently, our lab has also been investigating the molecular evolution and phylogeography of pathogenic bacteria such as MRSA and *V. cholera*. Phylogenomics and phylogeography of bacteria is a new exciting field of research, based on the analysis of genome-wide SNPs, using state-of-the-art phylogenetic methods and the Bayesian coalescent framework. Full genome bacterial sequences are obtained with the Illumina technology and analyzed with in-house pipelines implemented in the Galaxy software platform.

Lab 5
P4 & P7
Department of Biology
College of Liberal Arts and Sciences

My research is focused on the signaling and metabolic mechanisms underlying plant interaction with the environment. My lab research has been particularly focused on three topics: glucosinolate metabolism, guard cell signal transduction, and plant pathogen interaction.

Project 1. Glucosinolate metabolism. Glucosinolates are a group of naturally occurring thioglucosides, present in Brassica plants (e.g., canola and cabbage). Glucosinolate degradation products display diverse biological activities, including defense against insects and herbivores, N/S nutrition and growth regulation. From a human perspective, glucosinolate metabolites account for the distinctive flavors of cabbage and condiments. Some of the metabolites such as isothiocyanates exhibit anticarcinogenic properties. The core glucosinolate pathway has been well studied in Arabidopsis. However, we know little about how the components in different pathways interact to produce plant phenotypes and traits. Nor do we know how different layers of molecular control work together. The lack of such fundamental knowledge is a major reason why plant genetic engineering has been largely unsuccessful. It poses a chronic problem for rational engineering of crops for better quality and defense. Research in this project is focused on characterizing the regulatory and metabolic networks involving glucosinolate metabolism using multidisciplinary approaches. We aim to identify protein and metabolite changes in response to perturbation of glucosinolate metabolism and to integrate the data into glucosinolate networks. The process of networking will generate new testable hypotheses concerning glucosinolate metabolic pathways and related pathways. The ultimate objective is to use the immense biosynthetic potential of plants as an efficient, environmentally friendly and renewable source of fine chemicals and pharmaceuticals.

Project 2. Guard cell signaling networks. Guard cells are highly specialized plant epidermal cells that enclose tiny pores called stomata. Stomatal movements control both uptake of carbon dioxide and loss of water, and thus play important roles in plant growth and acclimation to environmental stresses. The plant hormone abscisic acid (ABA) is a key indicator of drought stress. ABA induces stomatal closure via an intricate intracellular signaling network in guard cells, thereby promoting plant water conservation. It is our central hypothesis that protein redox modification and dynamic changes in key metabolites are critical regulatory mechanisms in ABA signaling. We are
testing the hypothesis by pursuing: identification of guard cell proteins whose redox status is altered in response to ABA and determination of their specific redox-sensitive amino acid residues, quantification of ABA-induced changes in metabolites implicated in guard cell signaling, and integration of the new information into a dynamic model of ABA-induced stomatal closure. Accomplishing these objectives is significant because it will reveal novel components of ABA signaling networks and provide knowledge of regulatory mechanisms underlying stomatal movements that will help to develop crops with enhanced stress tolerance and productivity.

Project 3. Plant pathogen interaction. The study of pathogen response and defense in crop species is of essential importance as the applications are directly related to agricultural production. Pseudomonas syringae pv tomato (Pst DC3000) causes speck disease in tomato (Solanum Lycopersicum), a crop growing in large quantities in Florida and having both nutritional and economical value. The goal of this project is to take what is known about pathogen host interactions and observe in greater detail mechanisms that plants utilize in response to pathogen infection at the posttranscriptional levels, including protein expression, redox and phosphorylation/dephosphorylation switches. Understanding changes in protein expression as well as redox and phospho-switches will provide important insights into how plant response and resistance to pathogens are occurring. Further investigation into unique/novel proteins and regulations will advance our knowledge of plant defense against pathogens, and allow researchers to use biotechnology to prevent future bacterial speck disease outbreaks.

Interestingly, as we gain more and more knowledge, the above projects have become interconnected with each other. Glucosinolate metabolism plays a role in pathogen defense and affects stomatal movement, which serves as the first line of defense against pathogen invasion. In addition to hypothesis generation projects, another major part of my research program has been hypothesis driven, i.e., characterizing molecular, biochemical and physiological functions of specific genes and proteins identified by proteomics and metabolomics approaches. One of the projects has been focused on understanding the key steps in the methionine chain-elongation pathway, which directly connects methionine (primary) metabolism to glucosinolate (specialized) metabolism. Our integration of hypothesis generation and hypothesis driven research will ultimately lead to a holistic view of cellular networks and processes in plants and will create important stepping stones towards potential biotechnological applications in enhanced yield, bioenergy and defense.

Lab 6
P9 & P10
School of Natural Resources and Conservation
College of Agriculture and Life Science

This lab group in Quantitative Genomics Research is part of the Forest Genomics Laboratory. Research is focused in three areas: (1) Fundamental Genomic Research in the genetic regulation of gene expression and gene expression networks; (2) Applied Genomic Research for the discovery of genes, metabolic and regulatory networks that control variation in wood quality, growth and other important traits for the forestry and agronomic industry; and (3) Technology and genomic tool development.
APPENDIX B
SUMMER RESEARCH EXPERIENCE APPLICATION

Summer Research Experience 2016

* 1. Name (first and last)
   
* 2. Gender
   
* 3. Home Address
   
* 4. Home Phone Number
   
* 5. Cell Phone Number
   
* 6. Email Address
   
7. Alternate Email Address - if your school email may not work over the summer, please provide an unrelated email address
   
8. Physical, Health, or Dietary Restrictions
   

**9. Shirt Size**
- Small (S)
- Medium (M)
- Large (L)
- Extra Large (XL)
- Double Extra Large (2XL)

**10. Ethnicity (for grant reporting only)**
- Asian
- Black
- Hispanic
- Native Alaskan
- Native American
- Native Pacific Islander
- White, not of Hispanic origin

**11. What topics do your students tend to find difficult? What do you normally do to help facilitate their understanding of these difficult topics?**

12. Do you feel that participation in the Bench program helped your teaching/student's understanding of the subject matter in your action proposal? Why or why not?

**13. If you participate in the research internship, what class and level would you like to target with your module? e.g. 9th grade general/honors bio? 11th/12th grade AP/IB/AICE? Biotechnology/Bioscience?**

**14. It can be hard to apply new ideas/activities in the classroom given known obstacles/limitations - not having enough time, exams, pacing guides and other district mandates, etc - how would you plan to work around these issues in order to implement the curriculum you will create?**
DATE: May 4, 2015

TO: Mary Jo Korely, PhD
PO Box 112010
Campus

FROM: Ira Fischler, PhD; Chair
University of Florida
Institutional Review Board 02

SUBJECT: Revision of Protocol #2014-U-0558

TITLE: Biomedical Explorations: Bench to Bedside, Phase II

SPONSOR: National Institutes of Health Science Education Partnership Award

Your request to continue your research protocol involving human participants has been approved. Participants are not placed at more than minimal risk by the research. You are reminded that any changes, including the need to increase the number of participants authorized, must be approved by resubmission of the protocol to the Board.

Re-approval of this protocol extends for one year from the date of the review, the maximum duration permitted by the Office for Human Research Protection. This approval is valid through May 15, 2016. If this project will not be completed by this date, please telephone our office (352-0433) at least four weeks prior to this date so that we can discuss the renewal process with you. If you complete the project on or before the date please submit the closure report to our office. The report can be located at http://irb.ufl.edu/irb02/irb-02-forms.html

It is important that you keep your Department Chair informed about the status of this research project. In addition, if your project is funded, you should send a copy of this project renewal notification to the Division of Sponsored Research, Awards Administration, P.O. Box 115500.

ISF:dl
Informed Consent – Bench to Bedside Research Fellowship

Title of Study: Biomedical Explorations: Bench to Bedside – Phase II
Investigator: Mary Jo Koroly
Contact Phone Number: (352) 392-2310

Purpose of the Study:
The purpose of this study is to investigate the insights and observations of in-service teachers on learning and disseminating science content while participating in a professional development program.

Procedure:
Those who choose to participate in the research fellowship will have previously participated in the Summer Institute portion of the program, where they were asked to provide basic demographic and academic information (e.g., race, gender, teaching experience, and academic background indicators). Participants will be asked once again to complete a retrospective survey to be administered at the conclusion of the research fellowship. Based on the specific learning objectives, as determined by the project director and the authors of each curricular module, this survey instrument will contain questions that ask respondents to rate their knowledge, skills, and attitudes in hindsight, i.e., before they started the program, as well as at the conclusion of the program.
Focus groups conducted at the end of the fellowship period will determine the participants’ perceptions of and experiences during the program. You will be asked to keep a short journal, written via the use of prompts created by the evaluation team; these will document and describe their participation in the Institute and their reflections about what they learned and how it relates to their own teaching. You will also be asked to maintain lab notebooks, congruent with current research standards, to chronicle their research activities.
In addition, participants will be asked to complete an online satisfaction survey as they progress through the fellowship, asking for evaluation of project components including laboratory/content selection, educational best practice sharing sessions, lectures, and available resources. We will also ask participants to rate the effectiveness of the fellowship pedagogy and satisfaction with facilities and planning. Further, we will assess teacher confidence in their ability to undertake the implementation of their curricular modules. As part of their implementation, teachers will be asked to evaluate learning outcomes seen in their classes via the use of tools such as pre- and post-test assessments, teacher and student reflections, and targeted teacher observations. Fellowship participants will undergo on-site observation during the school year.
In order to protect the participant’s confidentiality, you will be asked to use the alphanumeric code you created during the Bench to Bedside two-week summer institute.

Risks and Benefits of Participation
While there are risks involved in all research studies, minimal risk is expected for participating in this project. As teaching usually involves a great personal investment, we anticipate there may be feelings of tension or discomfort upon the discussion of such topics as learning processes and state guidelines for teaching; however, every effort will be made to provide a safe and supportive environment. Participants will not be identified by name in any reports of this research (see above). Our discussions will provide you with the opportunity for reflection and this process has been found to be very beneficial for teacher development. Additional potential benefits include a better understanding of the way individuals learn science content in a given context.

Time Required and Compensation
Informal interviews, conversations, feedback and member checking will occur throughout the professional development program. Depending upon the time at which the interview/conversation takes place, we expect that these will range anywhere from 10-30 minutes. There will be no compensation for participating in this study.

Approved by
University of Florida
Institutional Review Board 02
Protocol # 2014-U-0558
For Use Until May 15, 2018
Confidentiality
All information gathered from the study will remain confidential to the extent provided by the law. Your identity as a participant will not be disclosed to any unauthorized persons. Any references to your identity that could compromise your anonymity will be removed or disguised prior to preparation of research reports or publications. Only the researchers and the University of Florida Institutional Review Board will have access to the research materials, which will be kept in a locked file cabinet. Electronic records, such as data spreadsheets, will be stored on a password protected, secure server.

Voluntary Participation
Your participation in this study is completely voluntary. You may decline to participate in (any part of) this study, and refusal to participate will in no way jeopardize your participation in the professional development program or your academic standing. You may withdraw at any time. You are encouraged to ask questions about this study at any time during the research study.

Contact Information
Please feel free to ask any questions you may have about the study. You may contact Mary Jo Koroly at korolymj@cpet.ufl.edu or (352) 392-2310 if you have any questions or concerns. For questions regarding your rights as a research participant in this study you may contact the UFIRB Office, Box 112250, University of Florida, Gainesville, FL 32611-2250; phone (352) 392-0433.

Participant Consent
I have read the above information and agree to participate in this study. I am at least 18 years of age. A copy of this form has been given to me.

Participant Name (Please Print) ___________________________ Date ___________________________

Participant Signature ______________________________________

PI Signature ___________________________ Date ___________________________

Approved by
University of Florida
Institutional Review Board 02
Protocol # 2014-U-0058
For Use Until May 15, 2016
APPENDIX D
CURRICULAR TEMPLATE

**Curriculum Planning Template**
Completed sample curriculum: [https://www.cpet.ufl.edu/teachers/sre/curriculum/](https://www.cpet.ufl.edu/teachers/sre/curriculum/)

**TITLE PAGE:** Make it catchy while still conveying the overarching concept of the curriculum.

**CONTRIBUTOR PAGE:** Identify the author of the curriculum and any contributors who helped construct parts of the lessons. Include a section that thanks anyone who has helped test or review the curriculum, and provide contact information for any future questions regarding the curriculum.

**CONTENTS PAGE:** Create two table of contents. One for the curriculum guide itself that lists the different parts of the guide and their corresponding page numbers, and one for the lesson plans that include the name of the lesson and page numbers for each the lessons’ sections.

**AUTHOR’S NOTE PAGE:** This section explains how you became interested with the curriculum’s topic, your history with the topic, why you thought of using this topic for your curriculum, and what you hope students and teachers will gain from this curriculum.

**INTRODUCTION PAGE:** Explain how the curriculum enhances student learning by giving students the opportunity to learn science standards in a novel but captivating way. Summarize what the students will experience through the lesson sequence. Are they brainstorming, exploring, researching, discussing, building, becoming more curious, investigating, watching or role playing? Include a summative description of the lessons and their goals, and explain how knowledge is built as each lesson transitions to the next.

**CURRICULUM TIPS PAGE:** Outline the lesson plan format being used for each lesson. Create a template for your lesson plans by describing what each section of the lesson plan contains. Be sure to include a glossary of any teaching strategies that are utilized within the curriculum, like collaborative learning, groups, inquiry-based, etc. Additionally any icons used throughout the curriculum guide will be defined here under an icon key.

**LESSON SUMMARIES PAGE:** Pull the lesson summaries from the beginning of each of the lesson plans and place them on this page. Be sure to clearly label each summary. Lesson summaries are a 1-2 sentence summary of WHAT the lesson will cover and HOW this content will be covered (Lab? Discussion? Role play? Simulation? Lecture and demonstration? etc.)

**LESSON SEQUENCING GUIDE PAGE:** Create a suggested pacing guide that can be followed when using this curriculum.
VOCABULARY PAGE: Pull the defined vocabulary terms from the beginning of each lesson, and place them on this page, creating an alphabetized glossary of all the vocabulary words covered by the curriculum.

STANDARDS PAGE(S): Create a list of all the Next Generation Sunshine State Standards (or any other state standards) that is covered by the curriculum’s lessons. Put them in numerical order, include a description of the standard, and show what lesson each benchmark or standard corresponds with. A tally chart works well to organize this data.

BACKGROUND INFORMATION PAGE: Assume the teacher knows very little about your lesson topic. Provide accurate, thorough, and up-to-date information about your topic from reliable sources. Define all key vocabulary. Usually a minimum of 3 paragraphs and maximum of 2 pages double-spaced.

LESSON PAGES: Include a thorough step-by-step walk through of each lesson using the following template:

LESSON / ACTIVITY INFORMATION
TITLE: Make it catchy and convey the topic of the lesson.

KEY QUESTION(S): Identify key question or questions the lesson will explore.

*SCIENCE SUBJECT: Anatomy and Physiology, Biology, Earth/Space Science, Integrated Science, Physics, etc. (indicated for the unit – no need to do for each lesson within the unit)

*GRADE AND ABILITY LEVEL: Specify grade level range and ability of students (regular, honors). (indicated for the unit – no need to do for each lesson within the unit)

SCIENCE CONCEPTS: Identify key science topics. Try not to be too narrow.

OVERALL TIME ESTIMATE: Indicate total amount of time needed for the lesson.

LEARNING STYLES: Visual, auditory, and or kinesthetic.

VOCABULARY: List key vocabulary terms used and defined in the lesson. All terms should then be defined and indicated in **BOLD** in the “Background Information.”

LESSON SUMMARY: Provide a 1-2 sentence summary of WHAT the lesson will cover and HOW this content will be covered (Lab? Discussion? Role play? Simulation? Lecture and demonstration? etc.)

STUDENT LEARNING OBJECTIVES WITH NEXT GENERATION SUNSHINE STATE STANDARDS:
  The student will be able to...
  1.
2. etc.
Number your objectives for easy reference. Focus on what students will KNOW, FEEL, or be able to DO at the conclusion of the lesson, not what they are doing during the lesson. Use specific, measurable, observable verbs. Avoid general terms like “know,” “understand,” or “appreciate.” Include at least ONE objective for EACH subject area addressed. Remember that each objective will require at least one specific assessment. Correlate lesson objectives to state or national standards.

NEXT GENERATION SCIENCE STANDARDS (http://www.nextgenscience.org/next-generation-science-standards)
(Standards can be put in list form, since descriptions were provided earlier)
COMMON CORE STANDARDS (http://www.corestandards.org/)

MATERIALS: Sort materials and indicate number required for different types of grouping formats (Per class, Per group of 3-4 students, Per pair, Per student). Be as specific as possible. No need to list basic instructional items like paper, pencil, chalkboard, or overhead projector.

ESSENTIAL:
SUPPLEMENTAL:

BACKGROUND INFORMATION: Assume the teacher knows very little about your lesson topic. Provide accurate, up-to-date information from reliable sources. Define all key vocabulary. Usually a minimum of 3 paragraphs and maximum of 2 pages double-spaced.

ADVANCE PREPARATION: Explain what the teacher needs to do to get ready for the lesson, e.g., choose and mark a study site; prepare a solution; prepare a list of local organisms; obtain news clippings regarding an issue; etc.

PROCEDURE AND DISCUSSION QUESTIONS WITH TIME ESTIMATES: This is the “heart” of your lesson plan. Assume you are writing this lesson for a substitute teacher to follow. (They do not have any idea what to do unless you clearly explain it to them). Divide your procedure into numbered steps with time estimates (in minutes) for each step. Be specific. Don’t just say “Introduce concept of food webs.” Instead, explain HOW the concept will be introduced. Are you giving a brief lecture? Doing a demonstration? Asking a series of whole-class questions? Showing a film clip? When including discussion questions in a lesson plan, list specific questions to ask and provide sample acceptable answers in parentheses. Don’t just say: “Conduct a discussion of the impact of global warming.” Instead, list exactly what questions the teacher should ask.

ASSESSMENT SUGGESTIONS: Describe specific assessments for EACH objective:
For objective 1…
For objective 2… etc.

Don’t just say “Collect student worksheet “ or “Give an oral quiz.” Need to clearly indicate the exact question or task that will be used to assess each objective.
EXTENSIONS:

ACTIVITIES: Are there other activities you know of from other resources that relate to this lesson?

LITERATURE: Are there trade books, novels, journal articles, or other print materials that focus on the same topic(s) as this lesson?

RESOURCES/REFERENCES: List all print and/or web-based references/resources used for either lesson ideas or content background information. Provide complete citations for all references.

TEACHER PAGES: Include any material that teachers will need for the lessons. Jigsaw reading material, student reading material, worksheets for students, and answers for those student worksheets are just a few examples of material that could be included here. Be sure to label any material that is included. End this section with a lined blank page labeled notes, so teachers can jot down any helpful hints for future uses of the lesson.

BACK MATTER

RESOURCES AND REFERENCES: Include a list of resources needed for this curriculum with a place to purchase them and their estimated price. Subsequently, list any references used in the curriculum alphabetically and in a standard format (APA, MLA, etc.)

CONTENT ASSESSMENT: Provide a pre/post test for the curriculum, and provide an answer key for teachers.

CONTENT AREA EXPERT EVALUATION: Provide an evaluation an expert could use to assess the curriculum. This should include a section for the expert to write their name and job title, a section with questions regarding the curriculum overall, a section for general comments, and a section that allows them to comment on each of the lessons included in the curriculum.

TEACHER FEEDBACK FORM: Provide a feedback form that a teacher could use to review the curriculum. This should include a section for teachers to write their name, a section to review the curriculum overall, a section for feedback specifically about the curriculum guide itself, a section for evaluative questions about each of the lessons, and a section for general comments about each lesson.

STUDENT FEEDBACK FORM: Provide a feedback form that allows students to review the curriculum. Include a section for their name and their teacher’s name, a section with evaluative questions about each of the lessons, and a section that allows students the opportunity to give general comments for each of the lessons.
APPENDIX E
BIOMEDICAL KNOWLEDGE ASSESSMENT

Pretest / Posttest

Participant Code: _______________________

1) How are proteins made in an organism?
   A. Smaller subunits are randomly linked together to form proteins.
   B. A code indicates which smaller subunits get linked together to form proteins.
   C. A code indicates which larger molecules get broken apart to form proteins.
   D. Organisms eat proteins, but they do not make proteins.

2) Which of the following statements is TRUE?
   A. DNA is made up of proteins
   B. Proteins are made up of DNA
   C. DNA is made up of amino acids
   D. Proteins are made up of amino acids

3) Which of the following is TRUE about genes?
   A. Genes are traits.
   B. Genes are proteins.
   C. Genes are sequences of nucleotides.
   D. Genes are sequences of amino acids.

4) Which bonds are created during the formation of the primary structure of a protein?
   A. peptide bonds
   B. hydrogen bonds
   C. disulfide bonds
   D. phosphodiester bonds
   E. A, B, and C

5) The α-helix and the β-pleated sheet are both common polypeptide forms found in which level of protein structure?
   A. primary
   B. secondary
   C. tertiary
   D. quaternary
   E. all of the above

6) In the double helix structure of nucleic acids, cytosine hydrogen bonds to
   A. deoxyribose.
   B. ribose.
   C. adenine.
   D. thymine.
   E. guanine.

7) The liver is involved in detoxification of many poisons and drugs. Which of the following structures is primarily involved in this process and therefore abundant in liver cells?
   A. rough ER
   B. smooth ER
   C. Golgi apparatus
   D. Nuclear envelope
   E. Transport vesicles

8) Which of the following contains hydrolytic enzymes?
A. lysosome
B. vacuole
C. mitochondrion
D. Golgi apparatus
E. Peroxisome

9) If mammalian cells receive a go-ahead signal at the G1 checkpoint, they will
   A. move directly into telophase.
   B. complete the cycle and divide.
   C. exit the cycle and switch to a nondividing state.
   D. show a drop in MPF concentration.
   E. complete cytokinesis and form new cell walls.

10) When a disease is said to have a multifactorial basis, it means that
    A. both genetic and environmental factors contribute to the disease.
    B. it is caused by a gene with a large number of alleles.
    C. it affects a large number of people.
    D. it has many different symptoms.
    E. it tends to skip a generation.

11) Phenylketonuria (PKU) is a recessive human disorder in which an individual cannot
    appropriately metabolize a particular amino acid. This amino acid is not otherwise produced
    by humans. Therefore, the most efficient and effective treatment is which of the following?
    A. Feed them the substrate that can be metabolized into this amino acid.
    B. Transfuse the patients with blood from unaffected donors.
    C. Regulate the diet of the affected persons to severely limit the uptake of the 
       amino acid.
    D. Feed the patients the missing enzymes in a regular cycle, i.e., twice per week.

12) What is the effect of a nonsense mutation in a gene?
    A. It changes an amino acid in the encoded protein.
    B. It has no effect on the amino acid sequence of the encoded protein.
    C. It introduces a premature stop codon into the mRNA.
    D. It alters the reading frame of the mRNA.
    E. It prevents introns from being excised.

13) A frameshift mutation could result from
    A. a base insertion only.
    B. a base deletion only.
    C. a base substitution only.
    D. deletion of three consecutive bases.
    E. either an insertion or a deletion of a base.

14) Which point mutation would be most likely to have a catastrophic effect on the functioning of
    a protein?
    A. a base substitution
    B. a base deletion near the start of a gene
    C. a base deletion near the end of the coding sequence, but not in the terminator codon
    D. deletion of three bases near the start of the coding sequence, but not in the initiator 
       codon
    E. a base insertion near the end of the coding sequence, but not in the terminator codon

15) Which of the following best describes siRNA?
A. a short double-stranded RNA, one of whose strands can complement and inactivate a sequence of mRNA
B. a single-stranded RNA that can, where it has internal complementary base pairs, fold into cloverleaf patterns
C. a double-stranded RNA that is formed by cleavage of hairpin loops in a larger precursor
D. a portion of rRNA that allows it to bind to several ribosomal proteins in forming large or small subunits
E. a molecule, known as Dicer, that can degrade other mRNA sequences

16) In animals, embryonic stem cells differ from adult stem cells in that
A. embryonic stem cells are totipotent, and adult stem cells are pluripotent.
B. embryonic stem cells are pluripotent, and adult stem cells are totipotent.
C. embryonic stem cells have more genes than adult stem cells.
D. embryonic stem cells have fewer genes than adult stem cells.
E. embryonic stem cells are localized to specific sites within the embryo, whereas adult stem cells are spread throughout the body.

17) Tumor suppressor genes
A. are frequently overexpressed in cancerous cells.
B. are cancer-causing genes introduced into cells by viruses.
C. can encode proteins that promote DNA repair or cell-cell adhesion.
D. often encode proteins that stimulate the cell cycle.
E. all of the above

18) Sequencing an entire genome, such as that of C. elegans, a nematode, is most important because
A. it allows researchers to use the sequence to build a “better” nematode, resistant to disease.
B. it allows research on a group of organisms we do not usually care much about.
C. the nematode is a good animal model for trying out cures for viral illness.
D. a sequence that is found to have a particular function in the nematode is likely to have a closely related function in vertebrates.
E. a sequence that is found to have no introns in the nematode genome is likely to have acquired the introns from higher organisms.

Open Response Item

19) Certain human genetic conditions, such as sickle cell anemia, result from single base-pair mutations in DNA.
A. Explain how a single base-pair mutation in DNA can alter the structure and, in some cases, the function of a protein.
B. Explain, using a specific example, the potential consequences of the production of a mutant protein to the structure and function of the cells of an organism.
C. Describe how the frequency of an allele coding for a mutant protein may increase in a population over time.

Items 1-3 are from the AAAS Test Bank.
Item 19 is from the 2010 AP Biology Exam, Form B, Question 2, The College Board
APPENDIX F
PRIME PCK RUBRIC

From Gardner & Gess-Newsome, 2011

<table>
<thead>
<tr>
<th>Teacher Score</th>
<th>Topic</th>
<th>Reviewer</th>
<th>PCK</th>
<th>Date of completion</th>
<th>Date of review</th>
<th>Level of detail in reflection</th>
<th>Total CK Score:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Score</td>
</tr>
</tbody>
</table>

DIMENSION OF PCK

<table>
<thead>
<tr>
<th>LIMITED 0</th>
<th>BASIC 1</th>
<th>PROFICIENT 2</th>
<th>ADVANCED 3</th>
<th>SCORE/EVIDENCE</th>
</tr>
</thead>
</table>

CK: Understands concept & role of concepts in the discipline

---Accuracy

- All or mostly inaccurate:
  - Selected lesson does not address requested concept
  - OR
  - Selected lesson addresses requested concept, but there is a glaring inaccuracy or many small inaccuracies

- Somewhat inaccurate:
  - Selected lesson tangentially addresses requested concept OR
  - Selected lesson addresses requested concept, but there are a few small inaccuracies

- Mostly accurate:
  - Selected lesson accurately addresses requested concept and there are only 1 or 2 small inaccuracies OR
  - Selected lesson accurately addresses concept with no inaccuracies, but responses are too brief to be considered "advanced"

- Completely accurate:
  - Selected lesson accurately addresses requested concept with no inaccuracies, large or small

---Interconnections

- None of the possible connections between concepts and subconcepts are expressed
- Few of the possible connections between concepts and subconcepts are expressed
- Some of the possible connections between concepts and the nature of science are expressed
- Many of the possible connections between concepts and the nature of science are expressed

---Examples

- No appropriate, accurate examples provided
- Potentially appropriate, accurate examples of the concept provided but are not explicitly connected to the concept
- One appropriate, accurate example of the concept provided and explicitly connected to the concept
- More than one appropriate, accurate example of the concept provided and explicitly linked to the concept

Score
<table>
<thead>
<tr>
<th>DIMENSION OF PCK</th>
<th>LIMITED 0</th>
<th>BASIC 1</th>
<th>PROFICIENT 2</th>
<th>ADVANCED 3</th>
<th>SCORE/EVIDENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CxK: Understands how student variations impact instruction</td>
<td>No evidence of understanding of students' common prior conceptions/difficulties and how they might impact instruction</td>
<td>Narrow understanding of students' common prior conceptions/ difficulties and how they might impact instruction</td>
<td>Adequate understanding of students' common prior conceptions/difficulties and how they might impact instruction</td>
<td>Sophisticated understanding of students' common prior conceptions/difficulties and how they might impact instruction</td>
<td>Total CxK Score:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DIMENSION OF PCK</th>
<th>LIMITED 0</th>
<th>BASIC 1</th>
<th>PROFICIENT 2</th>
<th>ADVANCED 3</th>
<th>SCORE/EVIDENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PK: Relationship between rationale to teaching strategies</td>
<td>No rationale provided OR A rationale that does not establish a relationship between strategies and student learning</td>
<td>Simplistic rationale that establishes a weak or partial relationship between teaching strategies and student learning</td>
<td>Adequate rationale that establishes an accurate, but limited relationship between teaching strategies and student learning</td>
<td>A sophisticated rationale that establishes a comprehensive relationship between teaching strategies and student learning</td>
<td>Total PK Score:</td>
</tr>
</tbody>
</table>

| -- Completeness/ Soundness | No strategies are used that elicit prior student understandings | Limited strategies are used that elicit prior student understandings | Appropriately varied strategies are used that elicit prior student understandings | Highly effective and appropriate strategies are used, that elicit prior student understandings | Score: |

| --Strategies | No strategies are used that allow for student metacognition | Limited strategies are used that allow for student metacognition | Appropriately varied strategies are used that allow for student metacognition | Highly effective and appropriate strategies are used that allow for student metacognition | Score: |
APPENDIX G
PRIME PCK PROMPT

Imagine yourself as a biology teacher who has been tasked with teaching protein synthesis. According to the Florida Next Generation Sunshine State Standards, this construct is in the Heredity and Reproduction Standard and corresponds to the following grade 9-12 benchmark:

*SC.912.L.16.5 Explain the basic processes of transcription and translation, and how they result in the expression of genes.*

Even though you may not be certified to teach biology or have any experience or interest teaching biology, please answer as if you are. This is one of the content topics for the summer institute, and we are interested in understanding how everyone would approach this topic.

Answer the following questions about teaching protein synthesis, then complete the table to describe in a step-wise manner how you would teach protein synthesis to your class.

1. What larger unit does this topic fall in your classroom? How many 50-minute class periods would you plan for teaching this unit?

2. Within your unit, how many 50-minute class periods would you plan for teaching just protein synthesis?

3. What are the connections between the overarching concept of the unit and the sub-concepts within the unit, including protein synthesis?

4. Why is protein synthesis important in the study of biology?

5. What ideas about protein synthesis would you expect students to have before you begin the unit (i.e. their preconceptions)?

6. What might students struggle with when they study protein synthesis?

7. What are the advantages of the teaching strategies you use in this lesson?

8. What alternative teaching strategies might you consider to teach protein synthesis?

9. What are the primary teacher and student activities? (Please elaborate using the attached table.)
<table>
<thead>
<tr>
<th>Step</th>
<th>Teacher activities</th>
<th>Student activities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# APPENDIX H
## CURRICULUM DESIGN KNOWLEDGE SURVEY

Curriculum Design Knowledge Survey (Pre program)

Personal Identifier: ______________________ ______________________
Date: ______________________________________

For each of the following statements, rate your degree of agreement or disagreement.

<table>
<thead>
<tr>
<th>My understanding of:</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Slightly Agree</th>
<th>Slightly Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop goals, objectives, and pacing for curricular units</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Slightly Agree</td>
<td>Slightly Disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>Define a problem statement prior to the design of a curricular unit</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Slightly Agree</td>
<td>Slightly Disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>Identify and link groups of related standards and benchmarks</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Slightly Agree</td>
<td>Slightly Disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>Analyze state standards to identify each concept addressed within</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Slightly Agree</td>
<td>Slightly Disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>Create learning objectives which address each concept within the standards</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Slightly Agree</td>
<td>Slightly Disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>Design activities which follow a learning progression</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Slightly Agree</td>
<td>Slightly Disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>Adapt curriculum materials to make them relevant for my students, school, or community</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Slightly Agree</td>
<td>Slightly Disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
</tbody>
</table>

Huizinga, 2014

Reiser et al., 2003; Krajcik et al., 2008
<table>
<thead>
<tr>
<th>Design curriculum materials that align learning goals, assessment, and learning outcomes</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Slightly Agree</th>
<th>Slightly Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Huizinga, 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apply a logical, orderly method of identifying, developing and evaluating a set of planned strategies targeted for attaining the curricular goals</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Slightly Agree</td>
<td>Slightly Disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
<td>Hardre, 2003</td>
</tr>
<tr>
<td>Clarify the instructional problems and objectives and identify the learners’ existing knowledge and skills before developing or adapting learning activities</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Slightly Agree</td>
<td>Slightly Disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
<td>Hardre, 2003</td>
</tr>
<tr>
<td>During the design of a curricular unit, identify learning objectives, assessment instruments, and learning exercises</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Slightly Agree</td>
<td>Slightly Disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
<td>Reiser et al., 2003; Krajcik et al., 2008</td>
</tr>
<tr>
<td>Create and assemble learning materials for a curricular unit based on the design plan</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Slightly Agree</td>
<td>Slightly Disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
<td>Huizinga, 2014</td>
</tr>
<tr>
<td>Engage in formative evaluation of a curricular unit by taking learners’ experiences and learning outcomes into account</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Slightly Agree</td>
<td>Slightly Disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
<td>Huizinga, 2014</td>
</tr>
<tr>
<td>Engage in summative evaluation of a curricular unit in order to assess student learning outcomes</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Slightly Agree</td>
<td>Slightly Disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
<td>Reiser et al., 2003; Krajcik et al., 2008</td>
</tr>
<tr>
<td>Generate ideas about how to make improvements to a curricular unit</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Slightly Agree</td>
<td>Slightly Disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
<td>Huizinga, 2014</td>
</tr>
</tbody>
</table>
Curriculum Design Knowledge Survey (Retrospective and Post program)

Personal Identifier: _________________________________________  Date: ______________________________________

For each of the following statements, rate your degree of agreement or disagreement.

<table>
<thead>
<tr>
<th>My understanding of:</th>
<th>Before the Summer Research Experience</th>
<th>After the Summer Research Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>Develop goals, objectives, and pacing for curricular units</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>Define a problem statement prior to the design of a curricular unit</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>Identify and link groups of related standards and benchmarks</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>Analyze state standards to identify each concept addressed within</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>Create learning objectives which address each concept within the standards</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>Design activities which follow a learning progression</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>Adapt curriculum materials to make them relevant for my students, school, or community</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>Design curriculum materials that align learning goals, assessment, and learning outcomes</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
</tbody>
</table>
Please turn over to complete the additional items.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Before the Summer Research Experience</th>
<th>After the Summer Research Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apply a logical, orderly method of identifying, developing and evaluating a set of planned strategies targeted for attaining the curricular goals</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>Clarify the instructional problems and objectives and identify the learners’ existing knowledge and skills before developing or adapting learning activities</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>During the design of a curricular unit, identify learning objectives, assessment instruments, and learning exercises</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>Create and assemble learning materials for a curricular unit based on the design plan</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>Engage in formative evaluation of a curricular unit by taking learners’ experiences and learning outcomes into account</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>Engage in summative evaluation of a curricular unit in order to assess student learning outcomes</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>Generate ideas about how to make improvements to a curricular unit</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
</tbody>
</table>
# APPENDIX I

## SCIENCE LESSON PLAN ANALYSIS INSTRUMENT (SLPAI)

From Jacobs, Martin, & Otieno, (2008)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Performance</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alignment with Endorsed Practices</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1.0</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1.1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alignment with standards</td>
<td>Exemplary (2)</td>
<td>Making Progress (1)</td>
</tr>
<tr>
<td>Direct and explicit links to appropriate NSES, state, and/or district process AND content standards.</td>
<td>Clearly contributes to students’ learning of one or more standards or benchmarks, which are not explicitly listed OR Either process or content standards are ignored.</td>
<td>Not well aligned with standards.</td>
</tr>
<tr>
<td><strong>1.2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awareness of science education research</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The lesson plan gives evidence that the teacher is knowledgeable about contemporary science education research on learning, teaching, and/or curriculum, and implements these ideas regularly and effectively.</td>
<td>The lesson plan gives evidence that the teacher is aware of contemporary science education research on learning, teaching, and/or curriculum, but may implement these ideas sporadically, ineffectively, or inappropriately.</td>
<td>The lesson plan is antithetical to commonly accepted research findings in science education.</td>
</tr>
</tbody>
</table>

| **2.0** | | |
| **Lesson Design and Implementation—Cognitive and Metacognitive Issues** | | |
| **2.1** | | |
| Goal orientation | Exemplary (2) | Making Progress (1) | Needs Improvement (0) |
| Explicit learning goals and objectives for the unit are comprehensive and clearly comprise a big idea of science. Lesson activities clearly support goals and objectives. | Learning goals and objectives are accurate but | Learning goals and objectives are not implied by the planned learning activities |
| | • are implied rather than explicitly stated | • reflect an inaccurate understanding of the topic |
| | • do not fully encompass the big idea of the topic area | • do not help students attain understanding of the big idea |
| | • are too vague to assess or include inappropriate level of detail | • are not reflected in the planned learning activities |
| | • are not completely supported by the lesson activities | |
| **2.2** | | |
| Content accuracy | Exemplary (2) | Making Progress (1) | Needs Improvement (0) |
| Factual information is accurate and complete with respect to standards and objectives. | Factual information is mostly accurate and may not completely reflect the learning goals or standards cited. | Inaccurate factual information or other errors are present. |
| 2.3 | Content presentation | Levels of detail and abstraction are challenging but accessible to most students; represents high expectations. The sequence of topics is appropriate. Appropriate examples are included. | Level of detail and/or abstraction is not challenging to a significant proportion of the class. Level of detail and/or abstraction is not accessible to a significant proportion of the class. The sequence of topics is somewhat disjointed. Appropriate examples are lacking. | Level of detail or abstraction is inappropriate for the course; reflects average to low expectations for all students. The sequence of topics seems random or illogical. Inappropriate examples are included. |
| 2.4 | Preassessment | The lesson plan is structured to actively solicit students’ preconceptions at the start of a topic, and refers to possible ways in which instruction could be modified in response to preassessment information. | The lesson plan does include preassessment activities, but information is not used to inform instruction OR teacher simply attempts to refute or replace misconceptions with correct information. | The lesson does not reflect an understanding that students’ preconceptions can affect how they understand new information. |
| 2.5 | Meaningful application | Content is given a meaningful personal context for students. Content is portrayed as significant to real-world issues. | Some attempt is made to give content a meaningful personal context or real-world significance. | Content is largely devoid of • real-world relevance • student-engaging context |
| 2.6 | Student reflection | Either individually or as a class, students are required to reflect on and summarize their understanding verbally or in writing at an appropriate point(s) during the unit in order to build conceptual understanding. | Lesson is structured to allow for (but not fully promote or support) meaningful student reflection or summation that furthers conceptual understanding. | Time is not reserved for student summation or other reflective practices. |
| 2.7 | Assessment | Includes effective tool(s) that assess for conceptual understanding • includes criteria and/or rubrics for performance-based assessments (reports, participation, etc.) if necessary • Assessment results used to modify the lesson as it is being taught, and as formative feedback to students | Includes tools or suggestions for assessment that may address conceptual understanding but emphasize factual recall. | Assessment tools do not measure student conceptual understanding OR there is no assessment tool or method described. |

### 3.0 Lesson Design and Implementation—Implementation—Sociocultural and Affective Issues

| 3.1 | Equity | Explicit attempts were made to address equity and access for underrepresented populations. | No mention of issues of equity or access. | The lesson suggests bias against identifiable populations. |
| 3.2 | Student attitudes about science | The teacher’s lesson objectives or activities are designed to affect a change in student values, attitudes, or beliefs about the importance and appeal of science, their ability or desire to learn science, etc. Student’s attitudes and beliefs are evaluated in order to measure progress toward these goals. | The lesson objectives and/or activities imply a desire for changing student values, attitudes, or beliefs about science, but no means for measuring such change is utilized. | Lesson objectives and activities are exclusively cognitive and include no implied desire for changing student values, attitudes, or beliefs about science. |
| 3.3 | Student engagement | Activities regularly engage students by promoting curiosity and/or motivating future learning. | Students are sometimes but not consistently engaged by activities or material OR activities engage students in a manner unproductive to learning. | Largely devoid of engaging or motivational content. |
| 3.4 | Student participation | Lesson regularly requires active participation of students in their own learning. | Lesson involves some level of student participation OR students are allowed but not required to participate in class discussions. | Little or no opportunity for student participation. |
| 3.5 | Classroom discourse—Fostering a community of learners | Students are part of a learning community:  
- Lesson is structured to require significant discussion among students focused on sense making  
- Lesson promotes evidence-based debate among students  
- Suggested open-ended questions for discussion are provided | Lesson is structured to allow for (but not require) meaningful student discussion that furthers conceptual understanding. | Lesson structure inhibits meaningful discussion. Teacher or text acts as authority figure who provides the “right answer” and curtails discussion. |
| 3.6 | Appropriate use of technology | Appropriate use of available technology (e.g., digital projector, laboratory probes, Internet resources). | Could better utilize available technology resources. | Inappropriate use of technology that distracts from learning goals. |
| 3.7 | Adaptability | Discusses ways to adapt the lesson to a variety of types of students (i.e., varying levels of achievement and interest, grade level, etc.). | Has potential to be adaptable to various needs, but is not explicitly addressed. | Narrow range of use (type of student, class size, etc.). |
| 3.8  | Variety and innovation | Innovative or creative approach, includes varying classroom activity to keep teacher and students engaged, including but not limited to:  
- teacher-designed or modified activities  
- interdisciplinary collaboration | May not be innovative or creative on the part of the teacher, but with enough variety to keep students engaged most of the time. | Mundane or boring to most students, and showing a low level of engagement of the teacher with the material to be taught. | 2 |

| 4.0  | Portrayal and Use of the Practices of Science |  |  |  |  |
| 4.1  | Use of hands-on exploration | Well utilized and integrated to promote student exploration and learning, and includes a meaningful assessment of that learning. | Used to verify topics, illustrate or apply processes after instruction has taken place OR Promotes student exploration and learning of content, but is not meaningfully assessed. | Used solely as diversions. Not integrated into the curriculum OR There are no appropriate hands-on experiences included in the lesson. | 2 |
| 4.2  | Nature of science | Reflects a sophisticated view of the nature and processes of science:  
- Explicit mention of how theories are tentative and develop and change over time based on new evidence or new treatment of previous evidence  
- Science is treated as a social endeavor involving argumentation and explanation | Reflects attempts to represent the nature of science:  
- Some mention of the tentative nature of scientific knowledge  
- Mixed messages about the nature of “truth” and the “right answer”  
- Illustrates the tentative and social nature of science, though exposure to the history of science in lieu of students’ own experiences | Treats science exclusively as a body of factual knowledge to be committed to memory AND/OR Treats experimentation exclusively as a way to find the “truth”. | 3 |
| 4.3  | Student practitioners of scientific inquiry | Students are consistently engaged firsthand in learning content through inquiry or doing science (questioning, experimental design, testing hypotheses or predictions, measurement and data analysis, drawing conclusions, etc.), rather than being told “answers”; inquiry process skills are taught in context. | Students do not engage in inquiry themselves, but do learn about inquiry as a scientific practice OR Some effort at engaging students in doing science is evident, with an emphasis on telling students science OR Inquiry is taught out of context as a separate content area, rather than as a set of process skills to be applied. | Students learn science exclusively by being told the accepted canon of scientific knowledge without discussion of how the knowledge was developed by scientists. | 3 |
| 4.4  | Analytical | Students are supported in drawing (or refuting) conclusions based on evidence in order. | Students are asked to draw conclusions based on evidence without sufficient and | Age-appropriate analytical skills are not developed because: | 3 |
Skills to develop their analytical skills; evidence may include quantitative data or qualitative observations.

Accurate teacher support or guidance; choice of variables, type of observation, etc. are not scaffolded appropriately for the students’ level OR Students are supported in developing higher order quantitative problem solving skills.

- there is no opportunity provided for students to analyze qualitative or quantitative data
- students are allowed to draw conclusions based on opinion or outside information, rather than evidence
- students use quantitative data to “plug and chug” using formulas to arrive at the “right answer”

| 4.5 Error analysis | Sources of experimental error and their size and effect on the experimental results and conclusions are discussed. | Sources of experimental error are treated simplistically. | Sources of experimental error are ignored or glossed over. | 1 |
SRE Daily reflections (administered in Qualtrics)

SRE reflection - Monday, June 27

Q1 Our end goal is to better understand the potential impact of each activity during the Summer Research Experience so we can design and deliver the most effective professional development programs to different contexts. To this end, we have a series of questions about each activity to investigate your experience in this specific professional development program. Please feel free to be a verbose as you wish. Just like each of our students learns in a different manner and comes into a situation with preconceptions, so too, do all of us. As adult learners, our needs are even more complex. I do not believe there is a one-size-fits-all PD model, nor is there one set curriculum that can be used in all contexts. I am confident your responses will support my hypothesis. :)

Q2 Your unique identifier is:

1 2 3 4
1. In the first space, enter the number of living siblings you have.
2. In the second space, enter the last digit of the cell phone number you most frequently use.
3. In the third space, enter the first letter of your mother’s first name.
4. In the fourth space, enter the first letter of your father’s first name. Please type your unique identifier below:

Q3 We have shared our goals for the program. What are yours? What do you hope to accomplish during the Summer Research Experience? Why did you accept the invitation to attend?

Q4 Today was a whirlwind to get you settled into your lab. What are your initial thoughts regarding your laboratory placement?

Q5 As you reflect on the day, are there any comments or concerns you would like to share?
SRE reflection - Tuesday, June 28

Q1 Now that you are settled in your lab, the daily prompts will ask you to consider your experiences within the lab setting as well as any additional programmatic activities. You will notice that the same prompts are used for each activity although some may seem more applicable than others for the various programmatic activities. Our hope is that you can use this venue to debrief and reflect on the day as well as organize your thoughts and focus your teaching and learning.

Q2 Please type your unique identifier below:

Q3 What did you do in lab today?

Q4 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following: Your personal learning
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q5 What dimension(s) of the activity most contributed to your learning? Please describe.

Q6 What dimension(s) of the activity hindered or had no impact on your learning? Please describe.

Q7 In your opinion, what could have made it more successful?

Q8 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following: Influencing your pedagogical practices
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q9 What specific changes do you envision to your pedagogical practice as a result of participating in this activity?
Q10 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following: Providing an experience that will result in how you design instructional episodes
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q11 What specific changes do you envision to your instructional design practice as a result of participating in this activity?

Q12 How engaged were you with today’s laboratory experience?
- Not Applicable (1)
- Very engaged (2)
- Somewhat engaged (3)
- Neutral (4)
- Not very engaged (5)
- Not at all engaged (6)

Q13 In your opinion, what could have made it more successful?

Q14 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s evening session was for the following: Your personal learning
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q15 What dimension(s) of the activity most contributed to your learning? Please describe.

Q16 What dimension(s) of the activity hindered or had no impact on your learning? Please describe.

Q17 In your opinion, what could have made it more successful?

Q18 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you
believe today’s evening session was for the following: Influencing your pedagogical practices
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q19 What specific changes do you envision to your pedagogical practice as a result of participating in this activity?

Q20 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s evening session was for the following: Providing an experience that will influence how you design instructional episodes
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q21 What specific changes do you envision to your instructional design practice as a result of participating in this activity?

Q22 How engaged were you with today’s evening session?
- Not Applicable (1)
- Very engaged (2)
- Somewhat engaged (3)
- Neutral (4)
- Not very engaged (5)
- Not at all engaged (6)

Q23 In your opinion, what could have made it more successful?

Q24 As you reflect on the day, are there any comments or concerns you would like to share?

Q25 That was the last prompt for today. The forward arrow will submit your responses. Thank you!
SRE reflection - Wednesday, June 29

Q1 Now that you are settled in your lab, the daily prompts will ask you to consider your experiences within the lab setting as well as any additional programmatic activities. You will notice that the same prompts are used for each activity although some may seem more applicable than others for the various programmatic activities. Our hope is that you can use this venue to debrief and reflect on the day as well as organize your thoughts and focus your teaching and learning.

Q2 Please type your unique identifier below:

Q3 What did you do in lab today?

Q4 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following:  

- Your personal learning
  - Not Applicable (1)
  - Very unsuccessful (2)
  - Unsuccessful (3)
  - Neither successful nor unsuccessful (4)
  - Successful (5)
  - Very successful (6)

Q5 What dimension(s) of the activity most contributed to your learning? Please describe.

Q6 What dimension(s) of the activity hindered or had no impact on your learning? Please describe.

Q7 In your opinion, what could have made it more successful?

Q8 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following:  

- Influencing your pedagogical practices
  - Not Applicable (1)
  - Very unsuccessful (2)
  - Unsuccessful (3)
  - Neither successful nor unsuccessful (4)
  - Successful (5)
  - Very successful (6)

Q9 What specific changes do you envision to your pedagogical practice as a result of participating in this activity?
Q10 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today's laboratory experience was for the following: Providing an experience that will result in how you design instructional episodes
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q11 What specific changes do you envision to your instructional design practice as a result of participating in this activity?

Q12 How engaged were you with today's laboratory experience?
- Not Applicable (1)
- Very engaged (2)
- Somewhat engaged (3)
- Neutral (4)
- Not very engaged (5)
- Not at all engaged (6)

Q13 In your opinion, what could have made it more successful?

Q14 As you reflect on the day, are there any comments or concerns you would like to share?

Q15 That was the last prompt for today. The forward arrow will submit your responses. Thank you!
SRE reflection - Thursday, June 30

Q1 Now that you are settled in your lab, the daily prompts will ask you to consider your experiences within the lab setting as well as any additional programmatic activities. You will notice that the same prompts are used for each activity although some may seem more applicable than others for the various programmatic activities. Our hope is that you can use this venue to debrief and reflect on the day as well as organize your thoughts and focus your teaching and learning.

Q2 Please type your unique identifier below:

Q3 What did you do in lab today?

Q4 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following: Your personal learning
   - Not Applicable (1)
   - Very unsuccessful (2)
   - Unsuccessful (3)
   - Neither successful nor unsuccessful (4)
   - Successful (5)
   - Very successful (6)

Q5 What dimension(s) of the activity most contributed to your learning? Please describe.

Q6 What dimension(s) of the activity hindered or had no impact on your learning? Please describe.

Q7 In your opinion, what could have made it more successful?

Q8 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following: Influencing your pedagogical practices
   - Not Applicable (1)
   - Very unsuccessful (2)
   - Unsuccessful (3)
   - Neither successful nor unsuccessful (4)
   - Successful (5)
   - Very successful (6)

Q9 What specific changes do you envision to your pedagogical practice as a result of participating in this activity?
Q10 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following: Providing an experience that will result in how you design instructional episodes
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q11 What specific changes do you envision to your instructional design practice as a result of participating in this activity?

Q12 How engaged were you with today’s laboratory experience?
- Not Applicable (1)
- Very engaged (2)
- Somewhat engaged (3)
- Neutral (4)
- Not very engaged (5)
- Not at all engaged (6)

Q13 In your opinion, what could have made it more successful?

Q14 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s evening session was for the following: Your personal learning
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q15 What dimension(s) of the activity most contributed to your learning? Please describe.

Q16 What dimension(s) of the activity hindered or had no impact on your learning? Please describe.

Q17 In your opinion, what could have made it more successful?

Q18 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you
believe today’s evening session was for the following: Influencing your pedagogical practices
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q19 What specific changes do you envision to your pedagogical practice as a result of participating in this activity?

Q20 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s evening session was for the following: Providing an experience that will influence how you design instructional episodes
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q21 What specific changes do you envision to your instructional design practice as a result of participating in this activity?

Q22 How engaged were you with today’s evening session?
- Not Applicable (1)
- Very engaged (2)
- Somewhat engaged (3)
- Neutral (4)
- Not very engaged (5)
- Not at all engaged (6)

Q23 In your opinion, what could have made it more successful?

Q24 As you reflect on the day, are there any comments or concerns you would like to share?

Q25 That was the last prompt for today. The forward arrow will submit your responses. Thank you!
SRE reflection - Friday, July 1

Q1 Now that you are settled in your lab, the daily prompts will ask you to consider your experiences within the lab setting as well as any additional programmatic activities. You will notice that the same prompts are used for each activity although some may seem more applicable than others for the various programmatic activities. Our hope is that you can use this venue to debrief and reflect on the day as well as organize your thoughts and focus your teaching and learning.

Q2 Please type your unique identifier below:

Q3 What did you do in lab today?

Q4 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following:

- Your personal learning
  - Not Applicable (1)
  - Very unsuccessful (2)
  - Unsuccessful (3)
  - Neither successful nor unsuccessful (4)
  - Successful (5)
  - Very successful (6)

Q5 What dimension(s) of the activity most contributed to your learning? Please describe.

Q6 What dimension(s) of the activity hindered or had no impact on your learning? Please describe.

Q7 In your opinion, what could have made it more successful?

Q8 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following:

- Influencing your pedagogical practices
  - Not Applicable (1)
  - Very unsuccessful (2)
  - Unsuccessful (3)
  - Neither successful nor unsuccessful (4)
  - Successful (5)
  - Very successful (6)

Q9 What specific changes do you envision to your pedagogical practice as a result of participating in this activity?
Q10 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following: Providing an experience that will result in how you design instructional episodes
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q11 What specific changes do you envision to your instructional design practice as a result of participating in this activity?

Q12 How engaged were you with today’s laboratory experience?
- Not Applicable (1)
- Very engaged (2)
- Somewhat engaged (3)
- Neutral (4)
- Not very engaged (5)
- Not at all engaged (6)

Q13 In your opinion, what could have made it more successful?

Q14 As you reflect on your first week, what are your thoughts regarding your experience so far?

Q15 How have your interactions with your lab host (faculty) and lab contact (graduate student, postdoc, staff) been?

Q16 This year we chose to pair everyone within the laboratory setting. How has that experience been for you personally so far?

Q17 That was the last prompt for today. The forward arrow will submit your responses. Thank you!
SRE reflection - Tuesday, July 5

Q1 Now that you are settled in your lab, the daily prompts will ask you to consider your experiences within the lab setting as well as any additional programmatic activities. You will notice that the same prompts are used for each activity although some may seem more applicable than others for the various programmatic activities. Our hope is that you can use this venue to debrief and reflect on the day as well as organize your thoughts and focus your teaching and learning.

Q2 Please type your unique identifier below:

Q3 What did you do in lab today?

Q4 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following: Your personal learning
   - Not Applicable (1)
   - Very unsuccessful (2)
   - Unsuccessful (3)
   - Neither successful nor unsuccessful (4)
   - Successful (5)
   - Very successful (6)

Q5 What dimension(s) of the activity most contributed to your learning? Please describe.

Q6 What dimension(s) of the activity hindered or had no impact on your learning? Please describe.

Q7 In your opinion, what could have made it more successful?

Q8 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following: Influencing your pedagogical practices
   - Not Applicable (1)
   - Very unsuccessful (2)
   - Unsuccessful (3)
   - Neither successful nor unsuccessful (4)
   - Successful (5)
   - Very successful (6)

Q9 What specific changes do you envision to your pedagogical practice as a result of participating in this activity?
Q10 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following: Providing an experience that will result in how you design instructional episodes
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q11 What specific changes do you envision to your instructional design practice as a result of participating in this activity?

Q12 How engaged were you with today’s laboratory experience?
- Not Applicable (1)
- Very engaged (2)
- Somewhat engaged (3)
- Neutral (4)
- Not very engaged (5)
- Not at all engaged (6)

Q13 In your opinion, what could have made it more successful?

Q14 As you reflect on the day, are there any comments or concerns you would like to share?

Q15 That was the last prompt for today. The forward arrow will submit your responses. Thank you!
SRE reflection - Wednesday, July 6

Q1 Now that you are settled in your lab, the daily prompts will ask you to consider your experiences within the lab setting as well as any additional programmatic activities. You will notice that the same prompts are used for each activity although some may seem more applicable than others for the various programmatic activities. Our hope is that you can use this venue to debrief and reflect on the day as well as organize your thoughts and focus your teaching and learning.

Q2 Please type your unique identifier below:

Q3 What did you do in lab today?

Q4 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following:  
   - Your personal learning
     - Not Applicable (1)
     - Very unsuccessful (2)
     - Unsuccessful (3)
     - Neither successful nor unsuccessful (4)
     - Successful (5)
     - Very successful (6)

Q5 What dimension(s) of the activity most contributed to your learning? Please describe.

Q6 What dimension(s) of the activity hindered or had no impact on your learning? Please describe.

Q7 In your opinion, what could have made it more successful?

Q8 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following:  
   - Influencing your pedagogical practices
     - Not Applicable (1)
     - Very unsuccessful (2)
     - Unsuccessful (3)
     - Neither successful nor unsuccessful (4)
     - Successful (5)
     - Very successful (6)

Q9 What specific changes do you envision to your pedagogical practice as a result of participating in this activity?
Q10 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following: Providing an experience that will result in how you design instructional episodes
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q11 What specific changes do you envision to your instructional design practice as a result of participating in this activity?

Q12 How engaged were you with today’s laboratory experience?
- Not Applicable (1)
- Very engaged (2)
- Somewhat engaged (3)
- Neutral (4)
- Not very engaged (5)
- Not at all engaged (6)

Q13 In your opinion, what could have made it more successful?

Q14 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s evening session was for the following: Your personal learning
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q15 What dimension(s) of the activity most contributed to your learning? Please describe.

Q16 What dimension(s) of the activity hindered or had no impact on your learning? Please describe.

Q17 In your opinion, what could have made it more successful?

Q18 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you
believe today’s evening session was for the following: Influencing your pedagogical practices
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q19 What specific changes do you envision to your pedagogical practice as a result of participating in this activity?

Q20 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s evening session was for the following: Providing an experience that will influence how you design instructional episodes
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q21 What specific changes do you envision to your instructional design practice as a result of participating in this activity?

Q22 How engaged were you with today’s evening session?
- Not Applicable (1)
- Very engaged (2)
- Somewhat engaged (3)
- Neutral (4)
- Not very engaged (5)
- Not at all engaged (6)

Q23 In your opinion, what could have made it more successful?

Q24 How are you feeling about your curriculum development?

Q25 As you reflect on the day, are there any comments or concerns you would like to share?

Q26 That was the last prompt for today. The forward arrow will submit your responses. Thank you!
SRE reflection - Thursday, July 7

Q1 Now that you are settled in your lab, the daily prompts will ask you to consider your experiences within the lab setting as well as any additional programmatic activities. You will notice that the same prompts are used for each activity although some may seem more applicable than others for the various programmatic activities. Our hope is that you can use this venue to debrief and reflect on the day as well as organize your thoughts and focus your teaching and learning.

Q2 Please type your unique identifier below:

Q3 What did you do in lab today?

Q4 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today's laboratory experience was for the following:

- Your personal learning
  - Not Applicable (1)
  - Very unsuccessful (2)
  - Unsuccessful (3)
  - Neither successful nor unsuccessful (4)
  - Successful (5)
  - Very successful (6)

Q5 What dimension(s) of the activity most contributed to your learning? Please describe.

Q6 What dimension(s) of the activity hindered or had no impact on your learning? Please describe.

Q7 In your opinion, what could have made it more successful?

Q8 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today's laboratory experience was for the following:

- Influencing your pedagogical practices
  - Not Applicable (1)
  - Very unsuccessful (2)
  - Unsuccessful (3)
  - Neither successful nor unsuccessful (4)
  - Successful (5)
  - Very successful (6)

Q9 What specific changes do you envision to your pedagogical practice as a result of participating in this activity?
Q10 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following: Providing an experience that will result in how you design instructional episodes

- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q11 What specific changes do you envision to your instructional design practice as a result of participating in this activity?

Q12 How engaged were you with today’s laboratory experience?

- Not Applicable (1)
- Very engaged (2)
- Somewhat engaged (3)
- Neutral (4)
- Not very engaged (5)
- Not at all engaged (6)

Q13 In your opinion, what could have made it more successful?

Q14 As you reflect on the day, are there any comments or concerns you would like to share?

Q15 That was the last prompt for today. The forward arrow will submit your responses. Thank you!
SRE reflection - Friday, July 8

Q1 Now that you are settled in your lab, the daily prompts will ask you to consider your experiences within the lab setting as well as any additional programmatic activities. You will notice that the same prompts are used for each activity although some may seem more applicable than others for the various programmatic activities. Our hope is that you can use this venue to debrief and reflect on the day as well as organize your thoughts and focus your teaching and learning.

Q2 Please type your unique identifier below:

Q3 What did you do in lab today?

Q4 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following: Your personal learning
   ○ Not Applicable (1)
   ○ Very unsuccessful (2)
   ○ Unsuccessful (3)
   ○ Neither successful nor unsuccessful (4)
   ○ Successful (5)
   ○ Very successful (6)

Q5 What dimension(s) of the activity most contributed to your learning? Please describe.

Q6 What dimension(s) of the activity hindered or had no impact on your learning? Please describe.

Q7 In your opinion, what could have made it more successful?

Q8 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following: Influencing your pedagogical practices
   ○ Not Applicable (1)
   ○ Very unsuccessful (2)
   ○ Unsuccessful (3)
   ○ Neither successful nor unsuccessful (4)
   ○ Successful (5)
   ○ Very successful (6)

Q9 What specific changes do you envision to your pedagogical practice as a result of participating in this activity?
Q10 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s laboratory experience was for the following: Providing an experience that will result in how you design instructional episodes

- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q11 What specific changes do you envision to your instructional design practice as a result of participating in this activity?

Q12 How engaged were you with today’s laboratory experience?

- Not Applicable (1)
- Very engaged (2)
- Somewhat engaged (3)
- Neutral (4)
- Not very engaged (5)
- Not at all engaged (6)

Q13 In your opinion, what could have made it more successful?

Q14 How was your second week in the lab? Was it different than the first? If so, how?

Q15 As you reflect on your laboratory experience overall, what are your thoughts regarding your experience?

Q16 How have your interactions with your lab host (faculty) and lab contact (graduate student, postdoc, staff) been?

Q17 This year we chose to pair everyone within the laboratory setting. How has that experience been for you personally?

Q18 That was the last prompt for today. The forward arrow will submit your responses. Thank you!
SRE reflection - Monday, July 11

Q1 Moving on to just a focus on your curriculum design process!

Q2 Please type your unique identifier below:

Q3 What did you focus on today during your curriculum design and writing process?

Q4 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s writing experience was for the following:  
   - Your personal learning
     - Not Applicable (1)
     - Very unsuccessful (2)
     - Unsuccessful (3)
     - Neither successful nor unsuccessful (4)
     - Successful (5)
     - Very successful (6)

Q5 What dimension(s) of the activity most contributed to your learning? Please describe.

Q6 What dimension(s) of the activity hindered or had no impact on your learning? Please describe.

Q7 In your opinion, what could have made it more successful?

Q8 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today’s writing experience was for the following: Influencing your pedagogical practices
   - Not Applicable (1)
   - Very unsuccessful (2)
   - Unsuccessful (3)
   - Neither successful nor unsuccessful (4)
   - Successful (5)
   - Very successful (6)

Q9 What specific changes do you envision to your pedagogical practice as a result of participating in this activity?
Q10 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today's writing experience was for the following: Providing an experience that will result in how you design instructional episodes

- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q11 What specific changes do you envision to your instructional design practice as a result of participating in this activity?

Q12 How engaged were you with today's curriculum design and writing experience?

- Not Applicable (1)
- Very engaged (2)
- Somewhat engaged (3)
- Neutral (4)
- Not very engaged (5)
- Not at all engaged (6)

Q13 In your opinion, what could have made it more successful?

Q14 Do you feel you spent enough time in the lab to design and write your curricular module? Why or why not?

Q15 As you reflect on your curriculum design and writing process overall, what are your thoughts regarding your experience?

Q16 That was the last prompt for today. The forward arrow will submit your responses. Thank you!
SRE reflection - Tuesday, July 12

Q1 Moving on to just a focus on your curriculum design process!

Q2 Please type your unique identifier below:

Q3 What did you focus on today during your curriculum design and writing process?

Q4 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today's writing experience was for the following: Your personal learning
   ○ Not Applicable (1)
   ○ Very unsuccessful (2)
   ○ Unsuccessful (3)
   ○ Neither successful nor unsuccessful (4)
   ○ Successful (5)
   ○ Very successful (6)

Q5 What dimension(s) of the activity most contributed to your learning? Please describe.

Q6 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today's writing experience was for the following: Influencing your pedagogical practices
   ○ Not Applicable (1)
   ○ Very unsuccessful (2)
   ○ Unsuccessful (3)
   ○ Neither successful nor unsuccessful (4)
   ○ Successful (5)
   ○ Very successful (6)

Q7 What specific changes do you envision to your pedagogical practice as a result of participating in this activity?
Q8 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today's writing experience was for the following: Providing an experience that will result in how you design instructional episodes
○ Not Applicable (1)
○ Very unsuccessful (2)
○ Unsuccessful (3)
○ Neither successful nor unsuccessful (4)
○ Successful (5)
○ Very successful (6)

Q9 What specific changes do you envision to your instructional design practice as a result of participating in this activity?

Q10 How engaged were you with today's curriculum design and writing experience?
○ Not Applicable (1)
○ Very engaged (2)
○ Somewhat engaged (3)
○ Neutral (4)
○ Not very engaged (5)
○ Not at all engaged (6)

Q11 In your opinion, what could have made it more successful?

Q12 How do you feel your curriculum is coming along? Are you happy with your progress?

Q13 Please describe previous curriculum design experiences you have had including formal training (coursework), professional development at conferences, district- or school-level activities.

Q14 How does this current Summer Research Experience compare to previous curriculum design experiences you have had?

Q15 That was the last prompt for today. The forward arrow will submit your responses. Thank you!
SRE reflection - Wednesday, July 13

Q1 Thank you all for taking time to talk with me and sharing your experience. :)

Q2 Please type your unique identifier below:

Q3 What did you focus on today during your curriculum design and writing process?

Q4 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today's writing experience was for the following:

- **Your personal learning**
  - Not Applicable (1)
  - Very unsuccessful (2)
  - Unsuccessful (3)
  - Neither successful nor unsuccessful (4)
  - Successful (5)
  - Very successful (6)

Q5 What dimension(s) of the activity most contributed to your learning? Please describe.

Q6 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today's writing experience was for the following:

- **Influencing your pedagogical practices**
  - Not Applicable (1)
  - Very unsuccessful (2)
  - Unsuccessful (3)
  - Neither successful nor unsuccessful (4)
  - Successful (5)
  - Very successful (6)

Q7 What specific changes do you envision to your pedagogical practice as a result of participating in this activity?
Q8 If we consider all dimensions of each activity this week including science content, teaching strategies, activity type, and setting, please indicate how successful you believe today's writing experience was for the following: Providing an experience that will result in how you design instructional episodes
- Not Applicable (1)
- Very unsuccessful (2)
- Unsuccessful (3)
- Neither successful nor unsuccessful (4)
- Successful (5)
- Very successful (6)

Q9 What specific changes do you envision to your instructional design practice as a result of participating in this activity?

Q10 How engaged were you with today's curriculum design and writing experience?
- Not Applicable (1)
- Very engaged (2)
- Somewhat engaged (3)
- Neutral (4)
- Not very engaged (5)
- Not at all engaged (6)

Q11 In your opinion, what could have made it more successful?

Q12 What did you think of Dr. Salemi's presentation? Did you feel it was beneficial? In what way(s)?

Q13 That was the last prompt for today. The forward arrow will submit your responses. Thank you!
As a form of evaluation and final holistic reflection on your Summer Research Experience, please consider the following question:

“How did you value the activity structures and design supports in the Summer Research Experience?”

On the graph, place a data point corresponding to your level of value of each of the activities 1 – 10 and connect those points with a line.
Please explain why you valued each activity to the extent indicated on the graph.

Activity structures and design supports
1 - Laboratory experience

2 - Daily reflection

3 – Evening session about design (Week 1)

4 – Interaction w/ former intern

5 – Group curriculum sharing (Week 2, evening)

6 – Friday lunches

7 – Curriculum writing (Week 3)

8 – Informal conversations with peers

9 – Individual curriculum discussion sessions (w/Julie or Houda)

10 - Presentation of designed unit
SRE Interview protocol

Thank you for talking to me today. I’m trying to understand teachers’ experiences in a teacher-scientist professional development program and the translation to a classroom module. Your participation is completely voluntary and you may withdraw at any time without penalty. Do you mind if I audio record our conversation?

You applied and were selected to return for the current three-week Summer Research Experience. Why did you want to attend? What did you hope to gain from the fellowship experience?

Were there particular experiences from the earlier institute(s) that motivated you to apply for the research fellowship?

How was your lab experience? Follow-up: mentor, having another teacher in the same lab – help, hindrance, neither? Would you recommend any changes for you personally?

How did you determine your lesson content and the sequencing of activities for the curriculum you are developing?

Did you have specific instructional goals in mind before you started developing your sequence of activities or did the activities direct the goals?

How has the experience of designing a curriculum been for you?

Have you ever done something like this?

Do you think it has been a valuable experience?

In what way or why not?

How could the experience have been improved for you?

What suggestions would you make for future programming?

What advice would you give future research fellows?
APPENDIX M
FIELD NOTES OBSERVATION CHECKLIST

Along with the daily reflections set up in Qualtrics for the teachers, a similar form will be generated for recording field notes.

Sample template for Monday, June 27, 2016

Date: Monday, June 27
Activity: Group orientation session
Location:
Who was present:
Activities:

Deepening subject matter knowledge:
(NA, Very unsuccessful, Unsuccessful, Neither successful nor unsuccessful, Successful, Very Successful)

Deepening pedagogical content knowledge:
(NA, Very unsuccessful, Unsuccessful, Neither successful nor unsuccessful, Successful, Very Successful)

Deepening curriculum design knowledge:
(NA, Very unsuccessful, Unsuccessful, Neither successful nor unsuccessful, Successful, Very Successful)

How engaged was each teacher with this activity?
(NA and Likert engagement scale with teacher names included in a table format)

Description of interactions between staff/teachers/scientists:

Description of informal interviews:

Overall reflection on and interpretation of the value of this activity:
Below are the curricula summaries written by the participants. Curriculum summaries were a design task due on the sixth day of the program and were described as a “paragraph describing the curriculum.” The summaries were then to be included in the final curriculum as an overview on the front page. These are followed by general comments from the scoring of the curricula by the two reviewers.

PARTICIPANT 1

Epigenetic inheritance provides an opportunity for students to revisit the transcription process in a manner that will reinforce understanding of the central dogma of molecular biology. Epigenetics as a theme of study incorporates concepts of molecular biology, gene expression, biochemistry, and implications for treatment of diseases or disorders that affect health and behavior.

In addition to transcription factors, students will be captivated by the idea that environmental exposures or stress may turn genes “on” or “off”. Using monozygotic twins as examples, students can easily comprehend how individuals with the same original genome diverge over time due to epigenetic influences. Creating interview questions to assess differences in monozygotic twins of different ages as a class activity will engage students to contemplate possible phenotypic changes produced by epigenetic changes in the twins.

Students will gain background knowledge through an interactive lecture that reviews transcription and includes the DNA methylation mechanism for epigenetic change. Background knowledge will be reinforced through video and slide presentations with assessments. A reading assignment using monozygotic twins for reference will also serve to reinforce content as well as provide an interesting example students will understand.

The lesson will conclude with a laboratory activity; Detecting Epigenetic DNA Methylation in Arabidopsis. This activity utilizes methylation-sensitive enzymes to explore epigenetics and gene expression that affects flowering in Arabidopsis plants. Students gain experience with DNA extraction, restriction enzyme digest, PCR, gel electrophoresis and bioinformatics.

Review: Because the individual pieces were not assembled into one whole curriculum, not all of the elements are present such as a comprehensive list of standards, references, and resources. The beginning pages state that this module is to be used after teacher lecture (not included) so it is not clear how much prior knowledge the students are to have. The use of the reading and videos on the mice and explanation of epigenetics are a nice way to introduce the content without the teacher lecturing. However, the accompanying teacher worksheets are very factual/recall based. It is suggested that if time allows, the students can do a "whole class discussion" (in quotes by the curric author as if this is an unusual pedagogical practice). A Science Take-Out kit is used to illustrate gene switches, however there is no indication that the lac operon in bacteria translates to epigenetic factors in other organisms. Supporting background information for the teacher and student is present and accurate, but very brief and does
not approach the depth of understanding that AP Biology students can and should possess.

PARTICIPANT 2

A bacterial based lab experience is one of the key components linking health issues with microbiology. This project is designed to reinforce prior knowledge and combine biogenetics lab practices, microscopy, and computer based research into a valuable and rich learning experience. The goal of this project is to influence student perception of bacteria’s place in the micro biome. When students begin to understand bacteria as members of a robust living, thriving community, they will be better equipped to understand the purposes underlying good health practices. The overshadowing objective of this lesson is to transform students’ perception of bacterium from a “germ” into a living thriving organism.

Review: There are no student worksheets/teacher guides to accompany the curriculum. The background information is minimal. While it does lay out a sequence of activities, there is not clear enough instruction within the curriculum for another teacher to actually implement. There are inconsistencies such as that the students are going to place their bacterial sequence in a phylogenetic tree, but then there is no evidence that the students do this. Likewise with the process of DNA sequencing. There is a bit of disconnect between the lessons which do not follow a logical learning progression. There are many NOS standards reported, but the activities really do not align and address them explicitly. The PCK and SMK are extremely weak in this curriculum.

PARTICIPANT 3

The purpose of this unit is twofold. First, to allow students to explore, and thus develop an understanding, and the ability to use, the processes of science. Second, to consider and evaluate whether or not practices that may cause harm to the natural environment also pose a risk to human health. The context for this exploration is environmental and human toxicology and the possible link between pesticide exposure and breast cancer. The unit will initially be designed for Advanced Placement Environmental Science and will follow a unit on pest control and pesticides. However, the unit could also fit easily into an advanced Biology or Anatomy and Physiology course. Much of the unit is student lead and teacher facilitated. As it is likely that every student has been impacted by breast cancer in one way or another, the unit will begin with a whole group discussion of their thoughts, perspective, and questions regarding breast cancer. Then, through a series of activities that will include brainstorming essential research questions, an exercise in how to read scientific papers with peer review, bioinformatics of cytochrome P450, and a bioassay, students will be able to evaluate and present results, make predictions (will justification), and propose questions for future research. The unit will include a pre- and post-test, a formative assessment in the form of a lab report/poster, and is expected to run seven 50-minute class sessions.

Review: Curriculum summary provides a description of what could be a great unit that really engages students to participate in the practice and process of science. Inferences have to be made based on the limited amount that is here right now, and much of the
scoring is based upon only one of the lessons that is most complete. Lesson one is missing although referred to as a lesson for brainstorming and posing research questions. Lesson three is also not developed yet. Lesson two is adapted from pompe. In the end, it has a lot of potential and scores relatively well, but it is not as complete as the others. This seems to be a weakness of the rubric.

PARTICIPANT 4

How can teachers introduce twenty-first century applications of protein Analysis into the classroom? By introducing peptide mass fingerprinting (PMF), students will be introduced to real world scenarios that everyday scientist work with day to day in a Proteomics Facility.

What is Proteomics? Why would teachers and students want to learn about the current applications in protein identification of cellular material, plant or animal? What is the purpose of protein identification? How would understanding the content help me become a better student or person within society? Can an across curriculum be designed for any science teacher to implement as a true lesson while still targeting the standardized testing learning goals? Throughout the three weeks, the SRE Interns asked the above questions while being exposed to a variety of cutting edge research. In the discovery process the below are some answers that the SRE Interns found out while working in the lab.

• Proteomics- the study of proteomes, large-scale study of protein structure and function.
• Teachers keeping up with current science applications maintain an exciting student-learning environment this is accomplished by teaching trendy content, look at science trends. Yes, science has trends.
• Students will transfer into critical thinking students allowing for college and the work force biotechnology applications to be carried in developing an educational portfolio.
• Protein Identification allows for scientist to pinpoint genetic responses due to favorable or unfavorable environmental stresses placed on an organism. Then the identified proteins may lead the pathway to desirable treatment or cure for societal and environmental diseases.

In addressing the above, the curriculum designed will incorporate: Pre-Lab Activities, Pre/Post Testing, Computer Research, Work force/College preparation Alternative Assessments, Teacher Links, Biotechnology Tips, and Extensions for Re-teaching or Technology incorporation.

Review: She seems to be trying to take on more than what is suggested with the title and goals. Effort is made to present cross-curricular connections, but also this is a bit distracting and convoluted. The sequencing of the activities makes sense, but within each lesson, there seem to be unconnected elements such as the cloze video on biofuels that isn't addressed other than a fill in the blank worksheet to accompany the video. Students do not engage in discussion and debate regarding what could be very fertile areas of conversation and allow a connection to be made between the plants they are to study and the real world. It is suggested in the first lesson, but then not addressed. The continual use of the phrase DNA fingerprint in connection with a physical human fingerprint is a glaring inaccuracy that only fosters common misconceptions regarding what DNA or protein fingerprinting really are. The curriculum
does always include objectives and make them known to the students. There are not many included, particularly considering the breadth of the unit. Some of the material - activities and assessments - seem rather low level. Dissecting a seed is a good visual, but something that should have been done in middle school.

PARTICIPANT 5

The amount of information, with respect to biology, has exploded. Bioinformatics is the use of computer technology to manage this information. It is important that students have a working knowledge of how to navigate these databases. The need for such databases was as a result of the vast amount of information obtained from the Human Genome Project. Bioinformatics includes the disciplines of computer science, statistics, mathematics, and engineering.

The concepts included in this curriculum are frequently taught as individual units and at different times during the curriculum. This can make it difficult for students to understand how these concepts are interrelated. Transcription, translation, protein structure and function, and use of databases are used to show how these concepts are not stand alone processes. While working in the lab, it quickly became apparent that the use of databases is an integral and vital tool in research. As biological data continues to expand at rapid rates, the field of bioinformatics is critical to the organization and management of this data. Students need to enter college with a basic understanding of how to navigate these databases. Utilizing databases gives students the opportunity to see how concepts, usually taught as separate topics, are actually dependent upon the integration of these topics.

The protein used in these lessons is cytochrome c. This protein was chosen for several reasons. The primary reason is that it is a protein recommended by IB. It is a fairly small protein, 150 amino acids long and it has only three EXONS. Cytochrome c is an ancient protein and so is found in nearly all organisms which makes it easy to align human cytochrome c with other species.

My hope is that students will be able to search for a human gene of interest and be able to align that gene with two or more other species to see the differences. They will be able to see on which chromosome that gene is located as well as the position and size. The number of EXONS is easily determined. Utilizing the differences between the species, a cladogram can be examined. Students will also take a section of that gene to transcribe and translate. Molecular visualization software will allow students to see the three dimensional structure of the protein. Secondary structures, alpha helixes and beta pleated sheets are easily seen in these models, thus reinforcing the structure of proteins.

Review: Overall the two lessons are presented well for the students as a list of instructions to follow. The exercises align well with the standards for the course and introduce bioinformatics well. This module is very focused on IB students (would work for AP as well) who are likely going to pursue higher education and who are more accustomed to direct teaching methods. Lesson one is simply a TED talk (which does a good job to engage and bring relevance of bioinformatics) and a review of mitochondria and the electron transport chain, pointing out the role cytochrome C plays. Since there is no scaffolding given for developing student understanding of these concepts, it again
is very restricted to IB or advanced students who have already learned the great detail about the production of ATP. Little content knowledge is provided for the students and teachers as the one lesson (lesson two) is really just a follow the direction and fill in the blanks. This is a great first step, but there is no elaboration or opportunity for students to explore other questions. This is hinted at as a tip to the teacher, but falls short. The AP Bio manual at least provides a bit of guidance for independent inquiry.

PARTICIPANT 6

Myotonic muscular dystrophy affects approximately 1 in every 8000 adults. It is the most prevalent form of adult muscular dystrophy. This is an RNA disease that is affected by methylation, changes in the polyadenyl tail, trinucleotide repeat expansion, RNA processing errors, structural changes that affect function, developmental switches in genes, and antagonistic regulation of proteins. By teaching about this one disorder, most of the AP requirements of epigenetics in Big Idea 3 and 4 can be addressed. In this short unit, discussions about complex gene regulation topics, paper models of RNA processing, and play-doh models of the more complex interactions will be used to explain the epigenetics of this disease. A simulated assay will be used to demonstrate a potential diagnostic tool.

Review: The curriculum is largely contained in the SMART notebook file. There are no student pages, no teacher pages. She references hands-on manipulatives with DNA sequences, but does not have these illustrated anywhere, no idea what the strands are supposed to look like. In the curriculum, she suggests there are video clips that would make use of additional technology, but there are none within the submission thus far. Students work with a white board once (with a partner) to illustrate their understanding of transcription. It is assumed there is some sort of formative assessment here, although this is not described in the teacher pages or alluded to in the SMART presentation. There is a fairly high level of content knowledge presented in the background information and in the presentation. It is very vocab intensive and text driven, not consistent with current learning theory. Although this is targeting AP Biology students (and IB) who are advanced learners, the information is presented in lecture format, without the opportunity for analysis, synthesizing, or application. For these higher level students in particular, this would be a good component.

PARTICIPANT 7

It is my intension with these lessons to have the high school student become familiar with the technological processes used in the proteomics field. Proteomics is not a one science field. It incorporates biology, chemistry, engineering and mathematics. Students usually take compartmentalized classes; just biology, just chemistry, just math. However, students must be aware of the interconnections of all these disciplines and how they play together in the latest cutting-edge research.

In the first lesson, The P4 Situation: Proteins, Proteomes, Photosynthesis and Plant Adaptation, they are introduced to the concepts necessary to understand the subsequent activities, from proteins to plant adaptation. This lesson targets many of the biology and chemistry standards. In the second lesson, What is your color?: Plant Protein Extraction and Colorimetric Protein Determination, the students learn about
Beer’s Law which allows them to measure concentrations of solutes in solution based on spectroscopy. This technique is then used to determine the concentration of leaf proteins in a sample extract. This technique is one of the student learning objectives for advanced science, like Advanced Placement® Chemistry (AP Chem). In the last and final lesson, Fragmented and Positive: Mass Spectrometry Peptide Analysis, and with the aid of animations and simulations, students are presented with the concepts of gel electrophoresis, mass spectrometry and bioinformatics. The students then will be analyze and identify proteins based on mass spectrometry data, using bioinformatics. Separation techniques and understanding the intermolecular forces disrupted by such techniques are learning objectives in the chemistry and in the AP Chem curriculum. Mass spectrometry analysis is also part of the student learning objectives in the AP Chem curriculum.

Review: Analysis and purposeful design is apparent in the sequence of activities which integrate well with an existing chemistry curriculum. Inclusion of biological systems and highlighting the chemical processes is a good reinforcement of prior knowledge and extends on that knowledge. Students in chem should have already taken bio in Florida. The students are very engaged in active learning strategies and must analyze and synthesize their findings. Formative and summative assessments are included that test beyond factual recall. How these are used to modify instruction is not made explicit, but that is not uncommon and is perhaps related to teacher's tacit knowledge? The connection between protein extraction and $A=abc$ is not clear, so that does present a gap in the sequence. Overall, well designed curriculum.

PARTICIPANT 8

Since the Human Genome Project was completed, the newly emerging field of epigenetics is providing a basis for understanding how heritable changes, other than those in the DNA sequence, can influence phenotypic variation. Epigenetics, essentially, affects how genes are read by cells and subsequently how they produce proteins. The interest in epigenetics has led to new findings about the relationship between epigenetic changes and a host of disorders including cancer, immune disorders, and neuropsychiatric disorders. The field of epigenetics is quickly growing and with it the understanding that both the environment and lifestyle choices can directly interact with the genome to influence epigenetic change. This unit is designed to provide a detailed look at the influence of epigenetics on gene expression through developmental stages, tissue-specific needs, and environmental impacts. Students will complete this unit with the understanding that gene regulation and expression is truly “above the genome” and well beyond the simplified mechanism of the Central Dogma of Biology.

Review: Outstanding designed curriculum. Attentive to SMK, PCK, and CDK. The sequence of lessons builds from student understanding of the central dogma and progresses from foundational knowledge to application. Ample opportunities for formative assessment. The amount of material is intense, but because of the varied methods of instruction, provides good variation for the student and teacher. It is designed with a specific course in mind, but could also be easily used in other life
In the field of biotechnology many new techniques and advances have occurred due to the sequencing of the human genome. Current technology is outpacing existing technology especially in genetics. Qualitative genetics is an area that studies non-medallion traits to focus on phenotype changes. Current research is focused on linking phenotypes to applied applications in agriculture, medicine and other industry. The lessons in this unit provide information on using biotechnology applications in fundamental genomic research. Students will be investigating current technologies in Next Generation Sequencing such as real-time PCR using quantitative models (complex non-mendelian traits), and analyzing gene sequences of Pisium sativum genetic seed stock. The investigation will help students look into these new technologies being used in genomic research today.

These quantitative traits of study are looking closely at phenotype classes that are not clearly distinguished and variation in in degree rather than kind. The effect of many genes contribute to the phenotypic variation with small additive effects. Variation is caused by both environment playing a major role in plants and genetics. Phenotype = Genetics + Environment.

The use of genetic markers which are places in the chromosome where individuals are different. The types of markers used in qualitative research are single nucleotide polymorphism or SNP’s with is a mutation in a single base variation. This usually the variation between individuals (alleles) involve just a single base A, G. SNP’s have the most common form in genetic variation. We will investigate these methods which are QTL analysis and Illuminum Infinnium or single base extension. The technology is leading to whole genome sequencing in the future.

The analysis of these phenotypes are measured with linkage disequilibrium. The allele frequency at a specific loci position. As future generations occur, shorter regions on alleles appear due to recombination. These factors during meiotic reproduction include independent assortment and crossing over. If the alleles at 2 loci are not independent of one another they may have some correlation. That is where researchers can use SNP’s as genetic markers for studies on what the gene may be controlling. They are looking for genes that control traits.

There are new analysis techniques using these genetic markers to tell which parent contributes what piece of the chromosome. These associations of a trait on a specific locus may be controlling the trait. Quantitative Trait Loci Analysis and Association Genetic Analysis are two current methods that are looking at these quantitative traits.

The goal for agriculture and plant biotechnology is to identify certain breeding crosses to improve or make new products, find diseases and other applications to improve our lives.

**Review:** Very disjointed, sequence of activities suggests a learning progression; however there are many missing elements. Suggests using a flipping method for
instruction, but there is no indication of teacher follow-up to ensure understanding and synthesis of the videos and simulations the students watch. There is no opportunity other than the worksheets the students complete to assess understanding and re-teach or address misconceptions. Never is it made clear where the pea seeds come from, what the relevance is, or connections between the phenotype of the plant they are extracting DNA from and resulting genomic sequence data. Lessons are disjointed and not enough time is given to assist with learning. Quantitative traits and the mathematical analysis is very difficult to understand and part of the reason they are not normally addressed in the high school classroom. The general concept can and should be introduced, but there is not enough scaffolding for the students to actually understand what they are doing. Particularly considering the audience that this curriculum is designed for: agriscience students. The background knowledge presented for the teacher and student is virtually non-existent.

PARTICIPANT 10

This curriculum allows students to extend their thinking beyond Mendelian genetics by examining breakthroughs in genetics and genomics research; using the inquiry approach students will understand Isaak Newtons' familiar expression from 1676 regarding scientific discoveries. “If I have seen further, it is by standing on the shoulders of giants.” Through guided inquiry, students will build on their understanding of the genetic concepts emphasizing how biological information is passed from one generation to another.

This curriculum is developed with the intention of moving students beyond the seven traits they have learned about genetics in DNA. They will explore their learning in four lessons sequentially. Using Arabidopsis plants, students explore the nature of science through observations of traits to applying cutting-edge technology to extract, sequence their DNA, and analyze their sequence for SNPs. Furthermore, they will acquire critical thinking skills through reading various passages on current biotechnologies and their impact on human health and the environment.

My hope is that students will be thoroughly engaged in learning about the current information about phenotyping and biotechnologies from these four lessons. They will be enticed to know more, which in turns will lead to them applying Isaac Newton’s expression and make additional discoveries. They will know the different career paths in the scientific research realms and make more informed decisions about their lifelong careers.

Review: Nice attention to sequencing activities in a learning progression to scaffold student understanding of quantitative traits. Preassessment at the start of the unit with questioning, but no indication of common student responses and how to adjust instruction. Provides nice background information. Would have liked more with each lesson to provide more depth for teachers. Perhaps more ties to human health would maintain more student interest and application. Trait information for arabiadopsis along with sequence data (authentic) might be a nice inclusion to incorporate technology.

PARTICIPANT 11
This curriculum affords an opportunity for students to consider how much of an impact they have on the environment. Curiosity is piqued as students examine water samples collected from bodies of water near their homes and see micro-organisms swimming in the water. Students will become scientists as they identify the organisms. Next, they will read about some literature on everyday household items and determine which of these may be harmful to those micro-organisms. Students will take the role of environmental scientists as they setup experiments to test the effects of household items. In their final project, students will create posters to inform others of the harmful impact our everyday items have on the environment.

**Review:** Overall a nice sequencing of activities. Since the main goal seems to be helping students understand the impact of toxicants in the environment, I think more time could have been spent on daphnia and bioindicators. They are only looking at survival but not considering behavioral observations that would enrich this unit and help students understand there are long term impacts as well. The content that is provided is accurate, although it seems to be somewhat simplified for the level of the student. The teacher background information does not provide much more in terms of depth of knowledge and there are some inaccuracies. The jigsaw is a good idea, but there should be more reading or explanation of what an LD50 is so that students can make sense of the data given.
Activity structures and design supports which afforded design expertise.

<table>
<thead>
<tr>
<th>Code</th>
<th>Operationalized in the TSP PD program</th>
<th>Coded example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject matter</td>
<td>Content from scientists</td>
<td>It’s like taking over the way that not only I want my students to learn but taking over the way that I would like them to learn the information. I think all together it would probably make it a little bit more concrete in my head so I can translate it to the students. So making it myself … I can do whatever I want with it but at the same time I know where I am at and I know where I would like to be at the end of what I’m teaching. (P10, interview)</td>
</tr>
<tr>
<td>Learning</td>
<td>Explicit reflection on student conceptions of biomedical science topics during group session and design tasks</td>
<td>It allows to me to take something that is very high in intense science which is what they are doing in the lab and squeeze it down to a point that I need to take that information and present it to the students without the students falling apart on me. I need to almost like translate everything into their world. If I want to show them something that they will be interested in it has to be into their context, their world. C3 and CAM are not in their world. Again, it makes you think it makes you come up with ideas. It is important for them to know those concepts so that they understand that you can end up with genetic engineering and you could do plants that are going to be robust and crops that are going to be better and world hunger all that good stuff. So it makes you think in which way can I translate. How can I translate that high level information into a level that they can do and I think that that’s a good thing. (P7, interview)</td>
</tr>
<tr>
<td>Laboratory experience</td>
<td></td>
<td>Tell me to write a curriculum on bioinformatics I am going to go to the research. I’m going to go to the Internet. I can do research just like anybody can do research on bioinformatics and I can read all about it. I’m not going to be able to express my experiences and frustrations on how the biology field right now is not really a field but an integration of all the different math computer. You can’t get that from an online research. Now tell me to write curriculum on plants and how the adaptation can be studied with protein I could do a lot of reading but the experience I think is valuable. It’s been really valuable. Even some of my kids probably could do better research online then I can in some subjects. They are so savvy at it but then being in the lab its really valuable. (P7, interview)</td>
</tr>
</tbody>
</table>

As far as the content knowledge goes it was great. The people are wonderful. I love the students in his lab. Even him he is really nice although I think I’ve spoken to him for a total of fifteen minutes. The two students and even the undergrad were all really nice and very knowledgeable. (P6, interview)
My lab experience here has been great. I just said wow. (P4, interview)

For me it was perfect. It was definitely serendipity. It was a gap in my understanding. Part of my content that I need to deliver but a gap in my comfort level in teaching that topic so for me it was like ideal. It was perfect. (P8, interview)

I would set up two experiments got the first one when we did the potassium which is one of the ingredients of fertilizer they all lived so our concentration wasn’t high enough and then the one we used with the copper they all died so that one was too high. So we had to adjust and then the next time that we ran the experiment something happened. My control samples died which tells me something was wrong from the beginning. (P11, interview)

Instead of just listening to a presentation or being involved in a question and answer session actually seeing them in the process of trying to do an investigation or to ask questions or to be doing the science to where they can get to the point where they are making a presentation. (P3, interview)

I think it got clearer as we did some of the lab activities because where I threw my transformation now I know that if I want to do a plasma that’s after DNA extraction. The whole thing flipped my whole biotech II curriculum upside down about the way it really should be performed. That was interesting I’m like oh, I can’t do that here. I should be doing it here because that’s the application for it. (P9, interview)

I’m creating my own stuff. It’s all me. It’s simple and in my own words and on my own terms. (P11, interview)

We’re being introduced to more content. We’re being challenged in that information way beyond what’s in the textbooks. I think in much more relative ways and that is going to translate to what we take back to the students. That’s what’s going to make them I’m hoping in the development of the lessons that it’s going to be more real to them other than just information from the classroom from the textbook but that there is real purpose. (P3, interview)

So depth of knowledge definitely and practical application of that knowledge. Not just this is what it is in the book but this is what they are actually doing with that information. (P8, interview)

I think research experience in the case of getting real world applications to what I am using in the classroom. So instead of doing just a PCR, okay, we did a PCR great okay, let’s move on to something else how to process works from a resource point of view why do we sequence from DNA extraction to PCR to protein purification and so on and so on. These kids can get a

<table>
<thead>
<tr>
<th>Active learning</th>
<th>1st person experience with activities</th>
<th>1st person experience with the process of science</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group discussions</td>
<td>Creating an multi-lesson unit</td>
</tr>
<tr>
<td>Collective participation</td>
<td>Teachers share teaching practices Teachers participate in discussions of curriculum development in whole and self-selected groups</td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>We were sharing activities we do with each other. We were sharing websites we use. Talking about student problems and trying to get certain concepts across. We did a lot of that as well as talking about the lesson plans that we’re writing now. (P6, interview)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>It was beneficial to me from the standpoint of one just getting to know another peer and also being able to talk about things and brainstorm. (P3, interview)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I don’t think that we have talked much about personal things as much as we have talked about how could we use this, what are we doing, how are we going to present this. I think it’s really, really helpful. We were up until one and two talking about this. It helps you see another person’s perspective. I think if I was alone I would have quit. (P7, interview)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Speaking whole group, you know, if we are in the common area or cooking or eating lunch or doing whatever I think the variety of labs that we are in and being able to share those with each other. I think we have an awesome mix of teachers so that we all have like I am learning something from (P6) and (P5) because we don’t have an IB program at our high school. So that’s interesting the biotech that (P9) and (P4) are doing. Getting their little bits of feedback that they include I think that’s awesome. So I don’t know if that was deliberate. The selection of teachers from a wide variety of different experiences, different size school districts. That’s huge. (P8, interview)</td>
<td></td>
</tr>
<tr>
<td>Duration and time span</td>
<td>3-week summer program Informal, electronic follow-up throughout the year Classroom visit with implementation assistance if requested Interim implementation report and presentation Jan/Feb 2017</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I think that’s plenty of time to write. (P1) came up with a much easier like for my anatomy class I could have focused on the structure of human I could have made it so much simpler but I’ll be really happy with the epigenetics when I’m done. I ended up with six lessons but there’s three activities in each lesson. So I think that’s what’s taking me such a long time, it’s taking me a full day to get them kind of the way I want them. (P8, interview)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Length of time I think was good. (P9, interview)</td>
<td></td>
</tr>
<tr>
<td>Coherence</td>
<td>Program supports teachers in designing units aligned with district/state goals Exemplar materials aligned with state and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>real world connection of why we’re using this technology. (P9, interview)</td>
<td></td>
</tr>
</tbody>
</table>
|                         | My county put together a biology curriculum map that maps out the standard with the essential question, this is how many days you are going to have on this, this is your vocab terms. ...I used the standards and the questions. That was the easy part because they had already given me the standards and essential questions and some of the vocab. So I put that in and then as I’m sitting there doing some of the background I’m like oh you know they might need to know what this word means. So I’ve moved that up to the background or the vocab from my
I came with my actual pacing guide and figured out what benchmarks I would hit in teaching this information and how long it would take me to actually do it. (P10, interview)

I appreciate very much that you give us this because I'll tell you the truth on the other things that we were talking about before where we did lesson planning and that kind of thing that wasn't really template given and that kind of made you have the feeling that well they're sitting there with the attitude that you are going to do something and they have to have that for their part of the grant and whatever you give them they are going to criticize it which criticism is part of it anyway but you just got that idea that it was more the process and less the idea of idealistically creating something that was useful and reusable. (P2, interview)

I didn’t have a clue where I was going with my curriculum until like 5 o’clock that afternoon and I knew that I was going to have to do an overview and I was like oh no but having that relaxed situation that it just clicked, it just came, were able to process. (P3, interview)

I’m thinking more particularly the evening sessions they were informal but I thought extremely helpful and productive like with the articles that we had and it’s something that I typically wouldn’t have expected that I would have enjoyed those programs and those sessions but that was wonderful. (P3, interview)

I thought that would hook them in and then let’s identify some of those and then the next was let’s read about toxins and you had a jigsaw reading in the Pompe so I’m like let’s do that. (P11, interview)

I looked at what has been done. A lot of it is with chlorine; a lot of it with salt, experiments with looking at the heart rate and looking at nicotine, which is all great, but I wanted something different. (P11, interview)

I had to look at the overall goal because I wanted to figure out where am I going to end up and then go backward in figuring out from the goal what is it I need the students to understand or master in order for them to understand the overall goal of where I needed them to be. (P10, interview)

It’s more like okay I have an actual concept and I know that goal that needs to be understood before that concept can make sense and then working backward and figure out what are the key things I need to focus on to get that across to my students. (P10, interview)
I’ve always looked at standards. I use standard based instruction. I don’t know how anybody couldn’t but evidently people don’t. It’s forced me to really pay attention to the standards. It has forced to me to take the understanding by design, which I’ve done in the past to develop my own little units. Kind of thinking about thinking for myself and putting that all together to design a lesson plan rather than just I want them to learn this this is how I can get them to get there let’s just do that. It’s more in depth thinking about how the lesson is going to be structured. I’m not just looking at the final end product. I’m looking at all the little baby steps we do to get there and how I can assess their learning in each of the baby steps to make sure they are ready to go on to the next step. (P8, interview)

Some of the papers that you gave us were valuable too. (P7, interview)

J: What came first? The activities or your learning goals?
T: If I hadn’t read the article that you recommended before we went into it I would have said probably half and half. It’s difficult to separate the two. After reading the article and some of the activities that we did in our evening sessions that’s when I started focusing oh yes I love to have fun and I love my kids to have fun and I want them to have that success but I also want it to translate in are they taking away from this lesson actual content or meat that they can show that they have learned that information. So it helped to settle me down and to focus on that part because I get all excited oh let’s do this but I need to kind of become more grounded. (P3, interview)

Content, learning goals, activities. Activities for me are always supporting your goals, your learning goals. Activities are there to support and provide memorable experiences for the content. (P1, interview)

I’ve used backward design before so I’m not having a problem with that aspect. (P9, interview)
Activity structures and design supports which constrained design expertise.

<table>
<thead>
<tr>
<th>Code</th>
<th>Operationalized in the TSP PD program</th>
<th>Coded example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject matter learning</td>
<td>Content from scientists Explicit reflection on student conceptions of biomedical science topics during group session and design tasks Laboratory experience</td>
<td>They really focus on the splicing events and that is such a teeny, tiny part of what we teach. (P5, interview) I was much more the observer and I thought that I would have just a little more hands on. (P3, interview) Overall, I would have preferred to have had more hands on labs. I would have preferred to have been in the labs. Okay, this is what we do with that particular concept but for me I felt like how would I say this I’m not an auditory learner in a sense. I’m visual, I’m tactile. I would have preferred to have gone through this with somebody telling me why are we doing this again and then tell me the theory behind what I’m doing rather than tell me the theory and now I’m thinking and conceptualizing what is happening and then okay we’re going to put it all together by doing this. It didn’t work for me. (P10, interview) What they do in that lab first of all is not really not much of what they do is conducive to bring it to the classroom at the level that I teach. Second of all, we would never have half of that equipment that they have. I just think it was a little above what we could do or maybe we just don’t know how to bring it out. We didn’t get to do a lot and that was frustrating. We watched a lot but I understood that. (P5, interview) I have to be honest at first because I am kind of a control freak when it comes to making sure I understand what’s going on and that kind of thing to walk into a lab where I didn’t comprehend on day one everything that was going on was frustrating to me. So it took probably three or four days to get adjusted to the lab and study background information to bring my brain up to speed on what was going on in the lab. (P1, interview) I was just hoping that in that first week we would have had more of an established laboratory procedure because it was a little slow. (P9, interview) I feel like I’ve been playing a lot of catch up this week. I was playing catch up with bench to bedside but I played a lot of catch up this week and actually bringing what academic knowledge I had into a real world setting. (P2, interview) I did want to increase lab skills too although I don’t feel I got that this time. I did get academic knowledge. I was hoping for both but I got one. (P6, interview)</td>
</tr>
<tr>
<td>Active learning</td>
<td>Collective participation</td>
<td>Duration and time span</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>1st person experience with activities</td>
<td>Teachers share teaching practices</td>
<td>3-week summer program</td>
</tr>
<tr>
<td>1st person experience with the process of science</td>
<td>Teachers participate in discussions of curriculum development in whole and self-selected groups</td>
<td>Informal, electronic follow-up throughout the year</td>
</tr>
<tr>
<td>Group discussions</td>
<td></td>
<td>Classroom visit with implementation assistance if requested</td>
</tr>
<tr>
<td>Creating an multi-lesson unit</td>
<td></td>
<td>Interim implementation report and presentation Jan/Feb 2017</td>
</tr>
</tbody>
</table>

It's like going through a new process. When you go through a new process you get frustrated and then you see that you can do it and then you get frustrated again. Then you see you can really, really do it. It's not that difficult. (P7, interview)

I assume having another person we would be collaborating and doing similar things but in reality that's not what was happening. It was more like since I'm familiar with this content area I'm going to look at it this way and since your more focused within that content area you'd be looking at it that way. So in regards to bouncing ideas off the person that I was paired up with that's not what I thought. There was cooperation but we weren't collaborating. (P10, interview)

It was difficult for me because (P10) was very new at this and I do it in class pipetting and things like that. If I would have changed anything about the experience, it's that we would have done our labs separately. I know that's hard for them but it would have helped me because I had more advanced not that I'm great or anything I'm not my pipetting skills need work just like everybody else. I made mistakes but it seemed to slow the process down for me so I was getting frustrated. (P9, interview)

I think I am going a little slower than some people are possibly I'm not sure. At least according to (P5). (P5’s) like oh yeah I turned in lesson one and everything is done. I'm like okay I’m behind on that. I haven’t submitted lesson one yet. (P6, interview)

Today I got some information (from lab host) that now I have three days to put it down and revise it. You know make it work. I feel like rushed. If I had the extra week I wouldn't feel like I'm feeling right now. I'm like oh I'm going to write oh no I need to meet Julie. I want to make sure everything he told us is there but I know that I have a deadline that is in two days. (P7, interview)

I wish because now its crunch time and there’s just not enough time to do what I think I need to do. I know it’s very unpolished and I think that bothers me. It’s like very rough. (P5, interview)

I would have liked another week to write and write more. Make a bigger, longer unit with more lessons. I think that because I have heard a lot of teachers say well I have like eight ideas or ten ideas and now I have to narrow down. Another week of writing would produce more curriculum materials. (P1, interview)
Program supports teachers in designing units aligned with district/state goals. Exemplar materials aligned with state and national standards and district pacing guide. Curriculum template is provided.

...what we’re doing now is not in a lesson format that we are expected to have. So if I’m going to do it I still need to do lesson plans I would probably cut and paste but I still need to put it in the (district) template. (P7, interview)

I may have to revise like if I had to hand my lesson plans in to my administrator I need a one piece page or two page document that I need to give them like stuff they are going to evaluate on me. (P9, interview)

I think we are use to doing our own form and what our schools want us to do and it’s hard for us to break out of that mold. It’s just like okay the purpose of it is not to fit mine it’s to fit this project. Just a little frustration, that’s all. (P9, interview)

The templates are giving me a hard time so I’m just going to Word documents and I am going to copy and paste together. (P9, interview)

T: I think the template is fine. There’s some components that I’m not sure I like.
J: Such as?
T: I put all my background information in that beginning and I don’t want to rewrite it in every section. So I just put a note refer to the background information section. (P6, interview)

It was like giving birth but I do understand the framework that you gave us and its exact setting was something that was science related but it also was a little different then the kind of science that I deal with okay. It was based around literature and that kind of thing. Greatly respect it but it’s not really what I do and I realize also that you had a lot of lessons there. What like 8 lessons am I correct? (P2, interview)

After maybe two days in the lab having besides the survey having some product because I’m finding I’m going back and although I’m using a lot of the things we wrote last week. Those products that we produced. I’m altering them a little bit and pulling them in and using them. I think even more foresight more forethinking maybe the first week. I took lots of notes. Pages and pages and pages of notes the first week so I am going back and looking at those but I think maybe synthesizing those in some other way. It would have been not a huge assignment every night but something to force us to be a little more reflective of our experience in the lab not the philosophical ideas of the learning objectives necessarily but a product maybe. I don’t know what that would look like but even earlier writing. I would have been okay with even earlier submissions just to get the ball rolling in your brain. (P8, interview)

The other thing that I would probably suggest would be adding a little bit more. If we are doing half of a day of okay you need to be in the lab you are doing this or that there should be some time for debriefing one way or the other because realistically when you are working with one
person who has not been in the classroom, it’s difficult to debrief or figure out what’s going on. After the lab if you would have a time for debriefing with other educators where you can actually mingle and figuring out or bounce ideas it would probably make it easier for the curriculum development part. (P10, interview)

<table>
<thead>
<tr>
<th>Models and materials</th>
<th>Teacher-found and teacher-made lessons (self or peers)</th>
<th>Textbooks</th>
<th>Exemplar curriculum materials and resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explicit design model</td>
<td>Aspects of Understanding by Design will be used</td>
<td>Inclusion of the ADDIE model as primer to design</td>
<td>Designing learning-goals driven educative materials</td>
</tr>
<tr>
<td></td>
<td>Heuristics for developing educative curricular materials</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Pompe Predicament seems like it’s overwhelming. … every time I pick up the book it’s like oh my gosh look at all these pages. (P7, interview)

I'm not use to making teacher answer keys. (P9, interview)

I’m use to stealing and adapting. So starting from scratch is time consuming, which is why I steal and adapt cause who has time to do this for everything? (P5, interview)

I think of the activity first and then I see which are going to be the goals and then I tie the standards in there. Even though to be honest with you I didn’t do that this time because you had us pull the standards first. Normally I wouldn’t do it that way because the homework was due for the standards I pulled all the standards and then I said okay I’m going to do that but I already had in my head what activities were going to be so still I had the activities first and then I did the alignment to the standards. The activities weren’t developed but I had a pretty good rough idea what I was going to do. (P7, interview)
LIST OF REFERENCES


Brown, M., & Edelson, D. (2003). Teaching as design: Can we better understand the ways in which teachers use materials so we can better design materials to support their changes in practice. *(Design Brief). Evanston, IL: Center for Learning Technologies in Urban Schools.*


BIOGRAPHICAL SKETCH

Julie Bokor earned Bachelor of Science degrees in zoology and microbiology and cell science and a Master of Arts in science education from the University of Florida. She completed her Doctorate of Philosophy in curriculum and instruction while Assistant Director at the University of Florida Center for Precollegiate Education and Training.