PRESERVICE SCIENCE TEACHERS' CAPACITY TO PLAN USING TECHNOLOGY IN AN INTEGRATED TEACHER PREPARATION PROGRAM

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The important role of integrating technology in support of engaging instruction is undeniable. It is called for in the *Next Generation Science Standards* (Achieve, Inc., 2013) and has been promoted in countless publications (Warschauer, 2006; Goethals, Howard, & Sanders, 2004; Mishra & Koehler, 2006; Bell, Gess-Newsome, & Luft, 2008; Koehler & Mishra, 2009; Schmidt et al., 2009; Harris & Hofer, 2009). Despite this rich research base, relatively little is known about how teachers develop the capacity to carry out this work in the early part of their professional trajectory.

This study looked to unpack and understand how a small set (n=6) of preservice secondary science teachers (PSST) developed the capacity to integrate digital technology that supported engaged science learning into their instructional planning. The PSST studied were enrolled in a Master of Arts and Teaching and teacher certification program that focused on the teaching of practices and that had previously been shown to support growth of their pedagogical design capacity (Grossman et. al, 2010; Ross, 2014; Kessler & Cartier 2014). In order to investigate the development of PSST planning with technology the program instructor designed and leveraged a set of intervention lessons integrated in the pedagogy course sequence.

Analysis of PSST planning documents and interviews showed a consistent and positive development of PSST ability to plan engaging science lessons supported with digital technologies after pedagogy course intervention. Further, the results point to the impact PSST internship placement sites and mentor support can have on how this planning process develops. Lastly, in a departure from previous research, the data show that PSST leveraged a set of planning routines in order to manage the overwhelming amount of resources and factors required to plan responsive instruction. The identification of planning routines as a part of PSST developing pedagogical design capacity opens the door to a new line of research and represents a slight shift in how the field has thought about this construct and its development.

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1.0 INTRODUCTION

The rate of change of the technological resources available in schools has far exceeded even the most liberal expectations of educational technology experts in recent years. Since the early 2000s the nature of technologies available to teachers has shifted from overhead projectors, TVs, and calculators to tablets, digital projectors, smart boards, smartphones, just to name a few. This drastic shift in available technological resources has occurred in a relatively short period of time, given the typical nature of change in educational settings. For example, according to the National Center for Educational Statistics, the number of computers available for instructional purposes was 8.8 million (77% with internet access) in the year 2000. This represented a computer for every 6 students enrolled in a K-12 public schools. In just under 8 years the number of computers available for instructional purposes had grown to 15.4 million (98% internet access) or roughly a computer for every 3 public school students (NCES, 2010; NCES, 2013). Coupled with the rapid emergence of hardware resources is a transformation in the way learners are utilizing technology and their expectations for the role of technologies in the learning process. As Collins and Halverson point out, "technologies are changing the very ways we think and make sense of the world" (2009, pg. 11). At the beginning of this transformation of digital resources, students primarily used technology to obtain or *consume* information. Now, students utilize technology to both consume and *create* new information, and they have also taken on the role of *refining and developing* the technologies themselves. As an example, last year at the Apple Worldwide

Developer Conference 200 out of the 5,000 developers in attendance were under the age of 18 (Dilger, 2014).

In the context of this dramatic and fast paced change, researchers and teacher preparation programs are challenged to define effective ways of preparing preservice science teachers (PSST) to use technology in their classrooms. For the most part, teacher educators have addressed these challenges by offering dedicated technology courses in teacher preparation programs. Such courses are meant to teach PSST how to use certain types of technologies they might encounter in their everyday work. Traditionally, technology courses have focused on helping PSST learn how to use software packages such as Microsoft Office, learning software like *Blackboard* (Blackboard, 2015) or *Schoolog*y (Schoology, 2015), and tools such as lab probeware. In these courses, PSST also learn to use hardware like smart boards and document cameras.

There are three important shortcomings associated with the stand-alone technology course approach to teacher education. First, these courses have been mostly void of pedagogical instruction, instead focusing on the functions and workings of the software and tools (Hsu & Hargrave, 2000). This structure ultimately results in the preparation of teachers who can *use* technology in straightforward ways to find out information, rather than teachers who can support the work of students and themselves as they develop and design technology and technological resources that can be leveraged to *create* new knowledge. Second, the increasing speed of innovation around technology resources renders much of the content in these courses outdated almost as soon as they are developed and taught. Third, many teacher preparation programs struggle to mirror the technological resources PSST find in their permanent teaching sites, due to the increasing variety of technology options. For example, a teacher preparation technology course might choose to give teacher candidates in-depth instruction around Vernier lab probes; however, the school placement for these candidates might use one of the other three major probeware manufacturers, resulting in the PSST having to learn a different piece of technology than the one presented in their teacher preparation program.

All of this rapid development and change leaves teacher preparation programs with many unanswered questions: How do we prepare PSST to use technology if the technology we have been preparing them to use becomes outdated within a year or two? How do we best prepare PSST to productively engage with technology at their teaching sites? How do we help PSST to leverage the affordances of technology in their teaching strategies? How do we support PSST in thinking about technology in ways that allow them to leverage these ever-changing resources to positively impact the learning opportunities they provide their students?

In this dissertation I address some of these issues by presenting an integrated view of technology and pedagogy in teacher preparation. In this study, Master of Arts in Teaching (MAT) candidates learned to evaluate technology in the context of individual lessons (with respect to specific disciplinary learning goals) and to strategically incorporate technologies into lesson plans designed to support engaging learning opportunities for students.

1.1 AN ENGINEERING METAPHOR

In engineering fields, engineers who do design work are required to synthesize an abundance of information including knowledge about the materials they are using, the setting the work must take place in, the accepted norms of the field around security and safety, and the amount of money available for a project. All of this information, and more, must be considered in service of solving the specific problem facing the engineer. These engineering problems range from bridging a river to creating a communication device or building controls for power plants to synthesize new polymers. Although these problems seem very different, all of this work utilizes many of the same engineering principles, specifically, the ability to solve problems in a specific context using the particular tools available and working within given constraints.

Given the complexity of this work, one would expect good engineers to handle multiple factors at one time while solving a problem. On the other hand, novice engineers might struggle with multiple factors causing a compounding of issues along the way. A possible outcome for novices could be a prioritizing of single factors. This prioritization is a way to minimize the complexity of a situation in order to achieve at least a portion of the goal. Utilizing features of the local context and accepted engineering practices while accounting for confounding factors to address problems parallels the work we expect of teachers as they plan and implement instruction. That is, we expect teachers to utilize their knowledge of their students, the goals of the curriculum, various pedagogical practices, and available materials, including digital technologies, to plan and design engaging learning opportunities for their students.

This metaphor raises some interesting question about how teacher preparation programs prepare PSST to engage in the work of instructional engineering. In the engineering community the product of the work must function, the bridge must stand up to traffic and winds and river current, without bankrupting the city building the structure. In science education the product of PSST instructional engineering must be lessons that provide students opportunities to engage in work that allows them to build content knowledge while at the same time participating in practices associated with science. This vision of engaged science learning is outlined in the *Next Generation Science Standards* (NGSS Lead States, 2013).

1.2 NEXT GENERATION SCIENCE STANDARDS (NGSS)

An important starting point when considering how PSST are engineering instruction (planning lessons) is defining the type of instruction they will engage their students with in the classroom. The *Next Generation Science Standards* (NGSS Lead States, 2013) provide that starting point, and much more, by laying out an overarching vision of how to think about engaged science learning. This vision is supported by years of research in science education and developed by the National Research Council (Schweingruber, 2012). Discussed in much greater detail in section 2.1.1 of Chapter 2, the NGSS lay out a vision for science learning that includes students engaging with authentic problems and practices in order to develop knowledge of patterns, facts, and concepts. PSST must think carefully about how they will engineer such instruction and a major part of that process involves considering and addressing the factors and resources they have available to support such work.

One factor that PSST must consider is the curriculum materials they have access to in their placement sites. Traditionally, curriculum materials have been considered "instructional resources such as textbooks, lesson plans, and student artifact templates" that are developed by experts with specific intent for how these materials should be used (Forbes & Davis, 2010, pg. 820). Sherin and Drake suggest that as teachers use curriculum materials they develop what is called "curriculum vision" (2009). This is the ability to utilize curriculum materials to enact various types of instruction in order to achieve specific instructional goals. Teachers' ability to "perceive affordances, make decisions, and follow through on plans" constitutes their Pedagogical Design Capacity (Brown, 2009, pg. 29). Teachers' Pedagogical Design Capacity (PDC) can be developed over time with continued enactment of curriculum, and through active engagement with better-designed curriculum materials (Choppin, 2011; Brown 2009). This study takes the framework of pedagogical design capacity and applies it to non-traditional curriculum material, specifically, simulations and digital educational technologies, then explores the ways in which PSST develop the capacity to plan using those technologies in support of engaged science learning.

1.3 DEVELOPING INSTRUTIONAL ENGINEERS

To facilitate the development of PSST capacity for planning using digital technology, I have co-developed a teacher preparation pedagogy course curriculum that provides PSST with opportunities to identify, discuss, rehearse, implement, and reflect on key instructional practices. Through a series of in-class activities and reflections the PSST build their understanding of the NGSS Science and Engineering Practices (Table 1.1) (NGSS, 2013). They also engage in a number of approximations of pedagogical practices (Grossman et al., 2009) that involve the design and support of cognitively challenging and scientifically authentic learning tasks for secondary science students. Taking the various instructional practices and factors into account, the teacher preparation program provided the PSST with a clear model of instruction supporting engaged science learning: *5 Practices for Orchestrating Productive Science Discussions* (Ross, 2014; Smith & Stein, 2011; Cartier, et al., 2014; NGSS, 2013).

Table 1. NGSS Science and Engineering Practices

1	Asking questions
2	Developing and using models
3	Planning and carrying out investigations
4	Analyzing and interpreting data
5	Using mathematics and computational thinking
6	Constructing explanations
7	Engaging in argument from evidence
8	Obtaining, evaluating, and communicating information

With a central focus on pedagogical practices, the design of the PSST pedagogy course sequence studied relied heavily on the work of Grossman et al.'s framework for the teaching of practice (2009). We provided PSST with representations of the various pedagogical practices (Table 1.2), enabling them to recognize and name these key practices.

Table 2. Pedagogical Planning Practices (Cartier, et al., 2013)

Practice	Representation	Approximation
Formulate Learning Goals	Exemplar lesson plan	Card sort task – identify learning goals
Select or Design an Instructional Task	Samples of high cognitive demand and low cognitive demand instructional tasks	Lesson Plan 2
Anticipate Student Thinking and Responses	Fast Plant lesson (case)	Lesson Plan 2
Monitor Student Work	Moon Phase Sample monitoring tool.	Kinetic Molecular Theory role-play
Select Student Work for Sharing	Moon Phase Sample monitoring tool.	Kinetic Molecular Theory role-play
Sequence Ideas and Work Samples for Sharing	Kinetic Molecular Theory lesson (case)	Kinetic Molecular Theory role-play
Connecting Student Ideas to One Another and to Disciplinary Learning Goals	Kinetic Molecular Theory lesson (case)	Kinetic Molecular Theory role-play

PSST were then provided opportunities to approximate these practices in activities that ranged from less authentic role-play scenarios to a very authentic performance where the PSST had to launch a lesson to secondary students in their internship sites. Although occurring in very different settings, all approximations included extensive support of the PSST from the course instructor, their mentor teachers, and their field supervisors. These representations and approximations in combination with other activities allowed the PSST to build an understanding of what engaged science learning looks like along with the process and factors associated with planning for such instruction. These factors included things like content alignment, context resources, students and their backgrounds, learning goals and objectives, available class time, and assessments.

This course structure has been shown to support the type of engaged science lesson planning discussed above (Ross, 2013). As such, the initial structure of the PSST pedagogy course sequence leveraged these previously proven approaches and sequences in the development of the technology portion of the pedagogy course sequence, described in some detail below and in greater detail in section 3.2.

Once the PSST demonstrated the early competency of thinking and planning around the NGSS practices, they participated in a set of lessons designed to engage them in thinking about the role of digital technologies in instruction. To accomplish this, the practice of selecting a computer simulation by asking the PSST to evaluate the affordances and constraints of a simulation was approximated. Specifically, the PSST were given a clear set of lesson objectives and contextual constraints (grade level, type of student, available class time) and were asked to think about affordances and constraints of the simulation in support of the specific learning goals.

An important factor in leveraging computer simulations is that they allow for an almost unlimited number of examples of different technology structures and designs that can act as affordances and constraints in supporting a specific learning goal. Using simulations allowed for the work of evaluating and planning using technology to be decomposed into manageable pieces for the PSST. These pieces were then combined and built up over time (Choppin, 2011). The goal was ultimately to build an understanding in the PSST of how they could think about and leverage simulations in their instructional planning. Since many of the technologies PSST have access to in their classrooms are also void of curricular context, the ability to design instruction with simulations should be of value, in that the lessons learned using simulations should be transferable to other digital technologies.

Once the PSST finished working with simulations they participated in a lesson designed to get them thinking about other contextual factors that need to be considered when planning engaging instruction with technology. This additional complexity forced PSST to think about technological materials while dealing with more complex variables in service of the instructional goals. Factors such as student abilities, classroom routines, and time constraints are just a few of the interconnected issues that PSST needed to consider when engineering instruction.

1.4 THE STUDY

In this study PSST were encouraged to approach traditional curriculum materials as instructional engineers. Using an engineering context, PSST designed secondary science lessons, taking into consideration a plethora of variables (students' prior knowledge, school context, curriculum resources, etc). This design process included practices such as rewriting tasks, making specific student grouping choices, making formative assessment selections, and other instructional and tool adaptations to engage students in science learning. In the end, PSST designed instruction in service of teaching specific learning goals to a specific set of students in a specific context. In other words, through this design work PSST both developed and leveraged pedagogical design capacity (Brown, 2009) to design instruction. This cyclic process of developing understanding, utilizing that understanding in design choices, and reflecting in service of developing new understanding is a common theme in the engineering and design communities.

Interrogating the conditions under which PSST develop that capacity for effective design (instructional planning) using digital tools during their teacher preparation program is at the core of this work. More specifically the goal of this study was to understand the development of this capacity in PPST who are enrolled in the contexts of a Masters of Arts in Teaching (MAT) and Masters of Special Education with Academic Instruction Certificate (MOSAIC) programs. Using a mixed methods approach, this dissertation study addressed the following research questions:

I. How do PSST think about and try to use technologies in their instructional planning prior to program intervention?

II. Following intervention, what do PSST attend to (e.g. affordances and constraints, modeling ability, etc.) around the use of computer simulations in their planning?

    a. In what ways do the dimensions of planning that PSST learned earlier in the program relate to the way that they plan with computer simulations?

III. How do contextual factors impact the way in which PSST plan for lessons involving computer simulations?

IV. Do the PSST attend to the same or different considerations when planning lessons involving computer simulations compared to lessons involving other digital technologies?

V. Do PSST demonstrate patterns or changes in their planning around digital technologies over time?

1.5 SIGNIFICANCE

This study address a number of important issues surrounding the development of PSST capacity to plan engaging science instruction supported by technology. First, although some research has been conducted on how preservice teachers develop the ability to design high cognitive demand tasks (Ross, 2014; Eskelson, 2013; Smith et al., 2013, Forbes & Davis 2008), very little is known about how PSST develop that capacity while taking technological affordances and constraints into account (Kessler & Cartier, 2014). Through the examination of PSST pedagogy course assignments and interviews, this study aimed to understand what the development of this design capacity looked like over time. Next, this study provides insight into how we can assess and understand the impact of PSST technological pedagogical and content knowledge on there planning of engaged science instruction (Mishra & Koehler, 2006; Koehler & Mishra, 2009; Schmidt et al., 2009; Harris & Hofer, 2009; Niess, 2005).

Finally Brown suggests that research “is needed to learn about how teachers develop pedagogical design capacity the relationships between perception and mobilization of pedagogical affordances, and the degree to which other personal resources influence the emergence of PDC" (pg.30, 2009). While some have begun to explore these ideas, they have primarily focused on traditional curriculum materials (i.e., textbooks, lesson plans, worksheets)(Forbes & Davis, 2010; Choppin, 2011). Conducting this work with computer simulations and other digital technologies contributes to this literature in a way that has not been addresses previously by looking at the impact of how PSST think about non-traditional curriculum materials and the impact this has on their instructional planning.

1.6 LIMITATIONS

This study was conducted with a small group (N=6) of PSST who were enrolled in a MAT or MOSAIC teacher certification program at a large urban Midwestern university. All of the PSST had earned an undergraduate science degree with a GPA of at least 3.0 prior to enrolling in the program. Given this context, the PSST are not a representative sample of the PSST in the country and the findings are not necessarily generalizable to all PSST or teacher education programs.

Aside from simply conducting this study, I also served as a co-instructor for the PSST pedagogy course sequence and was the clinical field supervisor for half of the sample. In the role of co-instructor I was responsible for much of the instruction, grading, and feedback provided for the sample PSST throughout the pedagogy course sequence described in chapter 3. As the field supervisor for 3 of the PSST in this study I observed 6 lessons over the course of the study, including providing feedback on lesson plans prior to their teaching the lesson. Undoubtedly these interactions and feedback had an impact on some of the PSST development. Again, this limits the generalizability of the results along with possibly impacting some PSST response to the interview questions posed. As an attempt to limit this impact, I was carful to only conduct interviews around planning assignments that had already been graded and returned prior to our interview sessions. Also, each participant was reminded at the beginning of each interview session that nothing they said would have any impact on their course work and would be kept completely confidential.

Related to this course work, Although PSST planned and implemented their final course assignment of the fall semester pedagogy course within two weeks of the technology course intervention and before the end of the fall semester (described further in section 3.3), the PSST data and interviews for this assignment were not actually collected until the beginning of the spring semester (approximately a 3 week difference). This was in direct response to the learning needs of the students and the necessity for them to focus on completing other course requirements.

No research methodology is completely without flaws and this study is no different. As discussed in greater detail in chapter 3, a number of strategies were employed to triangulate data. One of the primary sources of data for this work comes from PSST written lesson plans. Despite using interviews centered on these documents as a way to unpack PSST thinking, the use of these plans as data is potentially problematic. A level of uncertainty exists around how much the coded results from this data are the product of the PSST developing a mastery of writing lesson plans or a true shift in their thinking and ability to consider different factors, including technology, in their planning. Although this uncertainty does exist, the results discussed in chapter 4 suggest that the PSST lesson plans were a demonstration of more than simply mastery of writing plans and reflected a deepening of their understanding of how to leverage resources in constructive ways in their planning.

Next, one of the instruments used to assess PSST technological pedagogical content knowledge (TPACK) was an experimental tool developed as part of this study (Koehler & Mishra, 2009). With such a small sample size the tool could not be adequately checked for reliability. That said, the tool does provide valuable and necessary insights into how the PSST thought about the work of planning with simulations in specific contexts. The results presented in this study were triangulated with other data to minimize this limitation as the PSST cases were built.

2.0 LITERATURE REVIEW

The overarching goal of this project is to prepare PSST to evaluate, select, and design instruction that leverages technology to support secondary science students' engagement in lessons that are grounded in the science and engineering practices (SEP) put forward in the *Next Generation Science Standards* (NGSS Lead States, 2013). To this end, I begin here by building an argument for why this is an important undertaking and how we might best prepare teachers during preservice education to accomplish this goal. First, I draw on the literature base to describe key features of engaged science learning. This is followed by a review of the research base on knowledge and important strategies that teachers employ to design and support this type of learning. Next, is an exploration of how PSST learn and the contexts that foster their learning. Finally, I explore the Five Practices model of instruction, originally developed within mathematics (Smith & Stein, 2011) and recently modified by science educators (Cartier, et al., 2014). In this chapter I develop a rational for how preparing PSST to integrate digital technologies within the Five Practices instructional planning and implementation process will enable them to plan for engaged science learning.

2.1 ENGAGED SCIENCE LEARNING AND NGSS

In the science education community, a push for engaged science learning has most recently and publicly manifested itself in the release of the *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2013). The NGSS is a collaborative document developed from the work of the National Research Council (NRC) of the National Academy of Sciences, the National Science Teachers Association, the American Association for the Advancement of Science, and the nonprofit education reform organization Achieve. The NGSS was developed in a two-stage process that began with the *Framework for K-12 Science Education* (Nation Research Council, 2012). This document was intended to provide an outline for a new way of thinking about both what learners bring to the exploration of science phenomena and how their understanding might be expected to develop (become increasingly sophisticated and aligned with canonical ideas) over time (Nation Research Council, 2012). The *Framework* emphasized the need for educators to design learning opportunities that " integrate the knowledge of scientific explanations (i.e., content knowledge) and the practices needed to engage in scientific inquiry and engineering design. Thus the framework seeks to illustrate how knowledge and practice must be intertwined in designing learning experiences in K-12 science education"(National Research Council, 2012, pg., 11). In other words, the *Framework* was intended to give a vision of science learning that is grounded in the latest research.

The importance of designing contexts that engage learners in the practices of science as a means to support their developing understanding of fundamental science knowledge is not a new idea in science education. In fact, this view of learning science has a rich history dating back to the Committee of Ten (National Education Association 1893) and played at least a small part in each of the major eras of science education reform throughout the 20^{th} century (DeBoer, 1991).

The NRC's *Framework* brought the idea of integrating content and practice into the 21st century in two ways. First, it incorporated the latest ideas in the cognitive and learning sciences. Previous standards documents focused on detailing the pieces of canonical knowledge that students should know, and the recommendations for target learning goals were based upon disciplinary experts' recommendations (AAAS, 1993). In the *Framework* document, the NRC not only outlined important information (facts, patterns, concepts) that students should know, but also drew on cognitive science research to articulate a set of learning progressions – descriptions of how students build on existing knowledge and develop new understandings throughout the K-12 experience (Alonzo & Gotwals, 2012; Duschl et al., 2011; Sawyer, 2006). Thus, recommendations for target learning goals were informed by empirical studies of how novices actually develop new knowledge in science. Second, the *Framework* included recommendations about how teachers should support learning by providing contexts in which students engaged in *science practices as a means to developing canonical science knowledge*. In other words, the Framework provided a coherent vision of "integrating content and practice" for K-12 learners.

The NGSS writing team used the *Framework* document as a starting point in a 14-step iterative writing and design process (Achieve Inc, 2014). The resulting NGSS document is organized around three specific dimensions: Practices, Crosscutting Concepts, and Disciplinary Core Ideas. Notably in the document are the set of 8 science and engineering practices (SEP) that "represent what the students are expected to do" (NGSS, 2014, Appendix F, pg., 1): (1) asking questions and defining problems; (2) developing and using models; (3) planning and carrying out investigations; (4) analyzing and interpreting data; (5) using mathematics and computational thinking; (6) constructing explanations and designing solutions; (7) engaging in argumentation from evidence; and (8) obtaining, evaluating and communicating information.

Of particular relevance to this research is how the NGSS provides a clear vision of engaged science learning. This vision involves students learning by engaging in the SEP's while developing new knowledge of patterns, facts, or concepts. As an example, in the section on developing and using models the NGSS suggests that students "develop, revise, and/or use a model based on evidence to predict the relationship between systems or…components" (NGSS, 2014, Appendix F, pg., 6). In this example we see how the integrations of the SEP (developing and using a model) is used while developing knowledge (pattern between the systems). This example can be easily brought out of abstraction when thinking about how students in an earth and space class might learn about the phases of the moon. In such a lesson students would develop and revise models of how the Sun, Moon, and Earth interact to produce the observable features of the moon.

In summary, the NGSS is the culmination of many years of research and development of an agreed-upon target for science education. It sets forth a clear goal – engaged science learning. And it raises the bar for instruction because in order to ensure that engaged science learning takes place, teachers need a sophisticated skill set that includes knowledge of student thinking, deep disciplinary knowledge, and the ability to design and support engagement in tasks that involve SEPs. In the next section, I explore these demands on teachers in greater detail.

2.2 TEACHING THAT SUPPORTS ENGAGED SCIENCE LEARNING

2.2.1 Better Instruction

Throughout the K-12 educational landscape the need for more engaged science learning has resulted in a call for better classroom instruction. The NGSS points to a vision of student work that involves engagement in much more than a traditional transmission model of instruction centered on the teacher (Schiro, 2008). As a result, if teachers are expected to provide students with the opportunities to be engaged science learners they are going to be required to do much more than simply giving notes, copying procedure heavy labs, or enactings prepackaged curriculum materials. Teachers are going to need to design and develop instruction that takes into account multiple content, contextual, and curricular factors. We call teachers who engage in this type of work *instructional engineers* (Ross, 2014; Ross, Kessler, & Cartier, 2014), as they are active constructors of the learning environment.

Acting as an instructional engineer requires teachers to engage in work that is very different from the traditional ideas associated with teaching. Teachers need to select and adapt tasks that enable students to engage with the SEPs while still focusing their attention on the underlying scientific ideas. Tasks like these are said to require high cognitive demand and have been shown to be difficult to implement (Stein et al., 1996; Smith & Stein, 2011; Cartier, et al., 2014). These tasks also require instructional formats and activities that look very different from traditional teacher centered classroom interactions. The *5 Practices for Orchestrating Productive Task-Based Discussions in Science* (discussed in greater detail in section 2.3.3) provides a model of how teachers might actually engage in such work.

Thinking about the role of the teacher and instruction in this way has interesting consequences for how we as a field think about teachers and teaching. A particularly interesting and relevant line or research involves how teachers' use curricular materials. In the next section I define curricular materials and outline a set of research around curricular materials relevant to the integration of technology in service of engaged science learning.

2.2.2 How Teachers Utilize Curriculum Materials

A significant and ever developing amount of educational research exists about how teachers use and think about curriculum materials (Harris, Mishra, & Koehler 2009; Brown & Edelson, 2003; Forbes; 2013; Frobes & Davis, 2008; Davis & Krajcik, 2005; Remillard, 2000; 2005). Across this work curriculum materials are considered lesson plans, textbooks, curricular programs, and lab manuals; just to name a few. Regardless of what they look like, curricular materials are the resources teachers utilize in the planning and implementation of instruction.

For years, curriculum materials have been a focal point in educational (specifically instructional) reform around improving students' engagement in science learning (Ball & Cohen, 1996, Cuban 1992, Brown 2002, Brown & Edelson 2003). Some researchers are seeking to understand the ways in which teachers combine curriculum materials and resources with personal knowledge and beliefs in order to design learning episodes that serve particular instructional goals (Forbes & Davis, 2010). All the while, these teachers must bear in mind how the context of their particular environment will impact their design choices. Teachers' ability to accomplish this design work effectively is considered a measure of their Pedagogical Design Capacity (PDC) (Brown, 2009).

In their work studying how teachers use curriculum materials to guide instruction, Brown & Edelson (2003) found that teachers' utilization or uptake of materials could be characterized in one of three ways:

- At one extreme teachers *offloaded* the responsibility for instructional decisions onto the curriculum materials. In cases like this, a teacher would follow the curriculum materials without any changes and follow implementation suggestions or directions given in the materials as closely as possible. Some researchers call this type of instruction *implementation with fidelity* (O'Donnel, 2008).
- At the other extreme, teachers sometimes *improvised* their own materials; they created new resources that were not part of the designed curriculum. Although the teachers may have improvised many of their own materials, this did not necessarily mean they failed to achieve the goals of the original curriculum. In fact, some of the cases provided in Brown & Edelson (2003) study demonstrated that successful instruction occurred when teachers crafted materials to meet the needs of their specific students and simultaneously supported their attainment of the target curricular goals.
- Finally, in the middle of these two extremes, teachers sometimes *adapted* materials. In this case teachers took existing materials and transformed them based on what they believed to be the desired instructional outcomes (Brown, 2009). As might be expected, this approach resulted both in instances where the adaptations were consistent with the original curriculum design and supported target learning goals as well as instances where the adapted materials diverged from the original curricular goals.

In their study of elementary teachers' pedagogical design capacity for inquiry, Forbes and Davis (2010) developed an elaborated version of Brown and Edelson's (2003) curriculum utilization framework. The elaborated framework includes the addition of *mobilization* as a dimension that describes teachers' use of curriculum materials. Mobilization in this context refers to a teacher's capacity to draw from different curricular resources. At one end of this continuum, the teacher is only utilizing a single set of curriculum resources, usually provided to them by the school. At the other end of this continuum, the teacher utilizes multiple curricular resources, many of which may not be associated with the original provided curriculum. Placing the mobilization and adaptation on an x-y axis we get four quadrants, each representing a different pattern of how teachers go about interacting with curriculum materials. These four interactions are distributed improvisation, distributed offloading, focused improvisation, and focused offloading (see Figure 1) (Forbes & Davis, 2010).

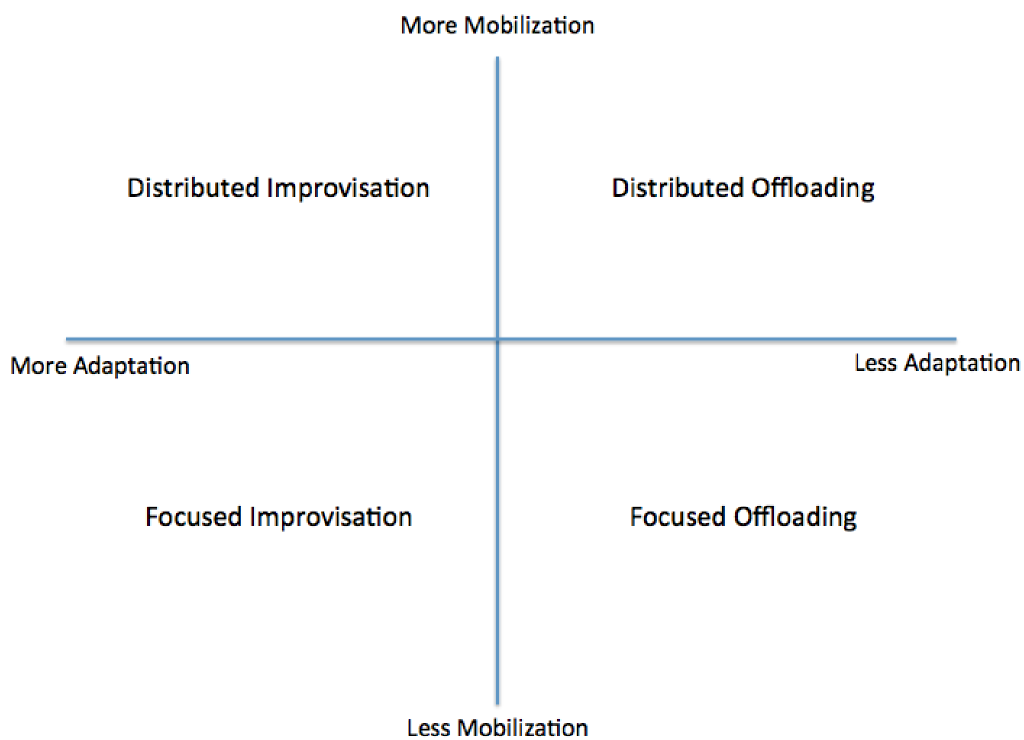


Figure 1. Forbes & Davis Curriculum Use Model

> Teachers who engage in *distributed improvisation* mobilize a wider variety of curriculum materials and actively adapt them. Teachers who engage in *distributed offloading* similarly use many different curricular resources but make fewer adaptations to them. Teachers who engage in *focused improvisation* use fewer curriculum materials but heavily modify and adapt those they do use. Finally, teachers who exhibit *focused offloading* use few curriculum materials and make few to no changes to them. (Forbes & Davis, 2010, p. 824)

All of these studies have focused on curricular materials in the traditional sense of the term. Curriculum materials in these studies include textbooks, written support materials for specific units, and other teacher lesson plans. This research study leverages the framework of adaptations and mobilization with non-traditional curricular materials, specifically, educational technology.

Before continuing on, it is important to define what is meant by the term technology. In the Technological Pedagogical Content Knowledge (TPACK) framework (discussed at length in the next section), technology is "broadly defined as 'the tools created by human knowledge of how to combine resources to produce desired products, to solve problems, fulfill needs, or satisfy wants' (Wikipedia, 2006)"(Koehler and Mishra, 2008). The framework goes on to specify that educational technology consist of both analog and digital technologies. Analog technologies are made up of things like pencils or microscopes and have a clear "transparency of function" (Koehler and Mishra, 2009). The idea behind the phrase "transparency of function" is that the possible ways in which you could use a microscope are clearly defined and accepted by a wide variety of teachers; little ambiguity exists about its function and purpose in relation to instructional uses. Digital technologies on the other hand consist of computers, blogs, and hand-held devices that can be utilized in many different ways. These digital technologies have a tendency to change or evolve quickly (Koehler and Mishra, 2008; Koehler and Mishra, 2009). Contrary to the analog technologies, these digital technologies have a tendency to have abstract uses, which are often dependent on the teacher and instructional goal being dealt with in a class. The technology portion of the TPACK framework does not actually differentiate between these two types of education technology; rather, it considers them both a critical part of the teaching practice.

In the remainder of this work I am going to use a more limited definition of educational technology. Moving forward, the terms educational technology, digital technology, or just technology refer to "the study and ethical practice of facilitating learning and improving performance by creating, using and managing appropriate technological processes and resources" (Richey, Silber, & Ely, 2008). These resources include, but are not limited to, things like electronic grade books, administrative programs, simulations, digital editing, web-based data systems, data collection probeware, smart boards, online assessments, collaborative wikis, social media, and computer simulations.

The focus of this section has been on what research says about how teachers take up working with curricular materials. If we are to develop an understanding of how teachers use technology resources, similar to those listed above, we need to first understand possible reasons why teachers take up work with curricular materials.

2.2.3 Factors That Can Impact Teachers' Use of Curriculum Materials

2.2.3.1 *TPACK*

Teachers' knowledge seems to be a cornerstone of their decisions around using curriculum materials. Technological pedagogical content knowledge or TPACK (Koehler & Mishra, 2009) gives a framework for thinking about that knowledge. TPACK has its theoretical groundings in Shulman's concept of pedagogical content knowledge (PCK). Schulman (1986) argued that PCK is the point between teachers' content knowledge (CK) and pedagogical knowledge (PK) that allows teachers to think about "the ways of representing and formulating the subject matter in order to make it comprehensible to others" (p. 9). Content Knowledge is a teacher's knowledge of the content matter they are expected to teach in their class. It includes things such as organizing frameworks, concepts, and accepted practices of the field (1986). On the other hand Pedagogical knowledge is a teacher's knowledge of the process of teaching, including all the practices and interactions that go into that process.

Research shows that low levels of science teacher PCK have been linked to teachers deciding to utilize recall questions or un-engaging questioning strategies (Carlesen, 1987). On the other hand high levels of PCK have been linked with novice teachers choosing "more engaging whole class instruction to present new materials or review student work" (Carlsen, 1991, pg. 646). Another study found that "the level of a teachers' PCK is highly connected with the degree to which his or her instruction is reform oriented" (Park, et al., 2011, pg 253). In that study, the authors make a clear argument for reform oriented instruction looking very much like the vision of engaged science learning outlined by NGSS and discussed in the first section of this chapter. The PCK research suggests that the higher the PCK the more likely science teachers are to use *reform oriented* curricular materials the way they were intended: to facilitate engaged science learning.

Although this research on PCK gives good insight into how pedagogical and content knowledge can impact teachers' work with curriculum materials, the TPACK framework takes these ideas a step further by overlaying technology. In their initial work with technological pedagogical content knowledge, (originally called TPCK and since renamed TPACK), Mishra and Koehler (2006) argue that Shulman's original conception of knowledge necessary for teachers to do their work is now missing a piece, technological knowledge. They argue that in order to develop good teaching in a modern classroom, a teacher must have content knowledge, pedagogical knowledge, and technological knowledge. They suggest, just as Shulman had argued about content and pedagogy, that technological knowledge is no longer a separate entity from content and pedagogical knowledge as a teacher attempts to find "ways of representing and formulating subject to make it more accessible and comprehensible" (Mishra & Koehler, 2006) to students. Rather, the authors put forward the idea that technology also overlaps with both content and pedagogy, ultimately leading to the concept of technological pedagogical content knowledge.

They further argue that good teaching also involves the interplay between these individual knowledge components. As shown in the diagram (Figure 2), this framework suggests that good teaching involves 7 knowledge dimensions: the three individual knowledge dimensions mentioned above (pedagogical, content, and technological), three binary interactions between any two of the original three knowledge dimensions (pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge), and finally, a tertiary interaction between all three knowledge types (technological pedagogical content knowledge).

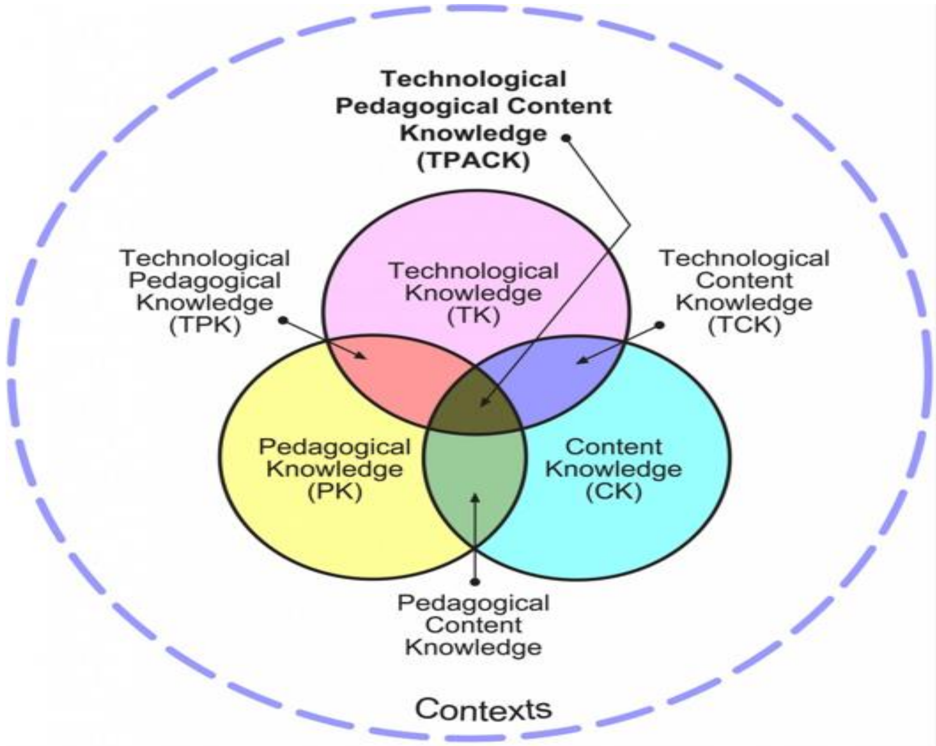


Figure 2. TPACK Framework
(image used with permission from http:/tpack.org)

The TPACK framework defines the technology knowledge (TK) portion of Figure 2 as the ability to use and understand various technologies (Schmidt, et al., 2009). This knowledge is constantly evolving over time as new technologies are developed and made available for personal and professional use. The second and third knowledge pieces are the same content knowledge and pedagogical knowledge from the Shulman (1986) work.

The first binary knowledge is technological content knowledge (TCK). TCK is the way in which technology and content come together to create new practices or knowledge. Both content and technology have major influence over each other and understanding how each impact one another allows for a better understanding of both. As an example, understanding how a gas chromatograph functions allows chemists to understand the results of experiments that utilize such technology and in turn allow for further development of chemistry theory and experimentation. The second binary knowledge is technological pedagogical knowledge (TPK).

TPK is how the use of different technologies impacts the practice of teaching and learning. For example, how a teacher may choose to structure a set of guiding lesson questions based on the resources available within a web simulation falls under the TPK category. The final of the binary knowledge components is pedagogical content knowledge (PCK). This is the same PCK from Shulman's work (1986) and previously discussed in this chapter.

The tertiary overlap of all three original knowledge pieces is technological pedagogical content knowledge (TPACK) and "is the basis of effective teaching with technology" as it leverages all of the knowledge dimensions together (Koehler and Mishra, 2009, p. 66). As an example, TPACK allows for a teacher to utilize their knowledge of what makes a concept difficult and how technology can help students address this while still attending to engaging learning practices. This combination points to how key technology is at facilitating students' opportunity to learn the content.

Although a significant amount of research has been conducted around the TPACK framework in the nine years since its first proposal, the educational researcher community is yet to come to consensus on developing ways of measuring these knowledge dimensions (Abbitt, 2011), understanding how they impact instructional and curricular choices (Harris & Hoffer, 2011), and determining ways to help teachers develop their TPACK (Chai et al., 2010; Nies, 2005). Results of this study should help inform the field about some of these issues as the various dimensions of TPACK will play a role in many of the instruments of this study (discussed in chapter 3).

2.2.3.2 *Other Factors*

Another implication centered around teacher knowledge, this time from the PDC literature, is that you can improve perservice teachers use of curricular materials by making links between “instructional goals and features and affordances of the curriculum materials” (Brown & Edelson, 2003, p. 6). A primary explanation for this is that many novice teachers have a difficult time figuring out how to select and adapt curriculum materials (Davis, et al., 2007; Valencia et al., 2006). Since teachers’ knowledge of how students learn is usually limited early in their carrier trajectory, teachers often choose to offload the work of thinking about how students will engage with tasks to the curriculum materials themselves. The logic teachers use in this decision involves their belief that the materials were developed by “*experts*” and they know better than the teachers how to engage students. This view is very different from one of an *instructional engineer*. An *instructional engineer* has the knowledge and understanding they would need to adapt the materials to fit their own specific students and context in order to engage their students in science learning.

When looking across the literature it is clear that a major difficulty facing teacher educators in improving PSST ability to plan engaging science lessons is their ability to select and adapt curricular materials (Ross, 2014). In the case of this research project, the materials PSST are selecting and using are digital technology resources in combination with other curriculum materials. Taken all together, in order to allow PSST to develop the ability to plan engaging science lessons using technology, this study will focus on getting PSST to engage in distributed use of curriculum materials as discussed in the Forbes & Davis (2010) section (section 2.2.2). Forcing PSST to work in this space aligns with the ideas of PSST as instructional engineers and leverages the 5 practices for productive discussion framework discussed later in this chapter.

2.2.4 How to Develop Teachers' Ability to Use Technologies

2.2.4.1 *Integrating Technology and Pedagogy Courses*

In a survey of teacher preparation programs, most preservice teachers only experience one course that was designed to "develop the basic technology skills that will serve as the foundation for their ability to integrate technology" in their instruction (Hsu & Hargrave, 2000). Yet, integrating technology into teacher preparation programs is vital if we are to transform "curriculum and instruction from the past to the future" (Warschauer, 2006 pg. 17). Collins and Halverson point out that in the future "people will need to develop skills to find the information they are looking for, to evaluate its usefulness and quality, and to synthesize the information they glean from the different sources they locate"(2009, pg. 10).

Teachers will need to be able to act as instructional engineers and avoid *offloading* instructional choices to *traditional curriculum* or adapting materials in ways that are ineffective. PSST will need to evaluate and manipulate these materials along with new technologies to create learning environments that support the type of learning outcomes promoted in the NGSS. As Goethals and colleagues point out, "integrating technology into teaching happens by design because teachers who do so have a proficient level of knowledge and expertise about using a variety of technologies in the classroom"(Goethals, Howard, & Sanders, 2004, pg. 61).

Thinking about the technological knowledge dimensions (technological knowledge, technological content knowledge, technological pedagogical knowledge, technological pedagogical content knowledge) in this integrated way is very different than most teacher preparation programs' approach to technology instruction. In many programs "technology is seen as being a separate and independent knowledge domain" (Mishra & Koehler, 2006, p. 1024). This means that technological knowledge can be taught in a separate vacuum from content or pedagogy. The result has been that PSST are taught how to use technologies such as software or mobile devices void of any specific discussion or instruction around how to teach with these technologies.

In fact, we see signals from many other facets of the educational community that appear to believe in this independent knowledge model. Many state agencies have begun to require that teacher certification programs demonstrate teachers "technological fluency" as part of the certification process. In most cases this fluency is demonstrated simply by showing future teachers were enrolled in a "technology course" (PA DOE, 2014). No mention of the content of that course or the nature of its instructional purpose (i.e., how the technology is integrated with content or pedagogy) is necessary to meet the requirements.

Looking at signals from educational agencies related to in-service development, we see that in 2006 the state of Pennsylvania also began to implement an incentivizing and capacity-building policy called Classrooms For the Future (CFF), which aimed to give schools and educators the educational technologies (including physical materials and training) necessary to bring the states' classrooms into the 21st century. The three most notable results were (PDE, 2008): (1) Technology use by teachers was inconsistent across districts, schools and teachers. (2) In many cases technology was not available when necessary. (3) Professional development mediated through, and designed around, technology was only occurring on an occasional basis.

Such signals from the state level, including large investments in tax dollars for improving educational technology access, suggest that having educational technologies as a pillar of PSST preparation programs align with the desires of the state policy makers. Even with such signals we still mainly see messages associated with access and technology-specific instruction, not instruction around technology in connection with pedagogy or content. With continued pressure from external stakeholders (Bill and Melinda Gates Foundation) and the research field providing supporting evidence (Bell, Gess-Newsome, & Luft, 2008; Collins & Halverson, 2009; Warschauer, 2006), the integration of educational technologies into all aspects of teacher preparation programs is critical if we aim to produce well-prepared teaching candidates in the current educational environment.

That said, a different approach to teacher preparation, one that the rest of this research project utilize, is to build an integrated pedagogy course that addresses the individual affordances and constraints of technologies for engineering engaging instructional tasks. Allowing PSST to view technologies as a resource, similar to other curricular resources, for achieving instructional goals rather than something to be used for its own sake, will encourage PSST to design instruction in ways that best suit their situations and students. In the next section, I look at a framework that drove many of the instructional choices in the MAT pedagogy courses studied in this work and that allows for such an integration of technology.

2.2.4.2 *Leveraging How PSST Learn Practices*

To achieve the goal of preparing PSST that are able to evaluate, select, and use technology to support students' engagement in lessons that are grounded in the NGSS, the MAT program at the center of this study leveraged the Grossman et al. framework for teaching practices (Grossman et al., 2009). Grossman and her colleagues identified "three key concepts for understanding the pedagogies of practice in professional education: representations, decomposition, and approximations" (p. 2058). In this framework, a practice is defined as one "that incorporates both intellectual and technical activities and that encompasses both the individual practitioner and the professional community" (p. 2059).

Decomposition of practice involves the division of practices into their individual parts. The goal of this decomposition is to draw the PSST attention to these individual practice pieces, build an understanding of how they work, and learn how to use these practice pieces in combination to achieve some instructional goal. For example PSST learn how to facilitate an effective lesson launch. This practice can be broken down into individual pieces: (1) connecting to previous work; (2) motivating students to participate; (3) communicating the purpose of the days task; (4) communicating expectations for the task. In order for a PSST to effectively launch a task they must develop an understanding of what each pieces does for the lesson and how to effectively implement them to achieve the overall practice.

Representations of practice illustrate to the PSST a specific piece or whole practice. When thinking about these representations of practice it is important to know that when the PSST are dealing with them, they are acting as observers. In other words, the PSST are observing how the practice manifests itself in some setting (case study, written classroom observation, a chart laying out steps in facilitating a discussion) that does not involve them as actors. For example, PSST might be asked to read a representation of the Lesson Launch practice described above. This representation could be an example section of the lesson plan that highlights all of the decomposed practice or a case study of how the different parts of a launch presented in a specific content.

Unlike representations, approximations of practice involve the PSST engaging in the practice. These approximations can vary in authenticity from high (the PSST is teaching a lesson that includes a launch at their placement site) to low (the PSST has to select a learning goal for a hypothetical context). Ultimately, approximations are opportunities for the PST to engage in working with the practices of being a teacher in ways that allow for reflection, evaluation, and improvement over time.

This framework is meant to give PSST the opportunities to engage with and learn how to leverage practices. In sections 3.2.3 and 3.2.4 I discuss the specifics of how decomposition, representations, and approximations of practice were used in the pedagogy courses within this study. In the next section I focus on the instructional model which the PSST program was developed around and that has its roots in the mathematics education literature. This particular instructional model was chosen because it (1) allows PSST to engage students in the SEP; (2) encourages PSST to draw on curriculum materials in distributed ways (Forbes & Davis, 2010); (3) can be decomposed, represented, and approximated to allow novice teachers the opportunities to learn.

2.3 INSTRUCTIONAL MODEL TO SUPPORT ENGAGED SCIENCE LEARNING

2.3.1 Demanding Tasks

The mathematics task framework is based on a student-mediated view of instruction and learning (Wittrock, 1986) that postulates that students' opportunities to learn in the classroom are shaped by the kinds of tasks with which they are asked to engage (Doyle & Carter, 1986). The framework specifies the ways in which the cognitive demand (CD) of mathematical instructional tasks can transform as they proceed through three phases: first as they appear on the pages of curriculum materials, then as they are set up by the teacher in the classroom, and finally as they are actually enacted by students (Stein et al, 1996). At each phase, instructional tasks are classified as requiring one of the following kinds of thinking: memorization, procedures-without-connection to concepts, meaning or understanding, procedures-with-connection to concepts, meaning or understanding, or "doing mathematics." The first two of these levels are considered to require lower-level demand while the latter two require higher-level demand (Stein et al, 1996).

A consistent finding is that the kind and level of thinking often declines as tasks pass from their curricular form to being set up by teachers and, again, to being enacted in some manner by the students (Hiebert & Stigler, 2000; Stein et al, 2000). Another major lesson from this work is that students who complete tasks at a high level of CD show better learning gains on equivalently high demand assessments than those who do not (Stein & Lane 1996). One of the key points of this work is that simply handing students high demand tasks is not enough to facilitate the learning gains desired in mathematics. As a result, an instructional model designed around facilitating discussions in mathematics was developed to foster the types of task interactions desired and necessary to produce successful student learning.

2.3.2 5 Practices for Orchestrating Productive Mathematics Discussions

Building on the work of leveraging high demand tasks as a way to positively impact learning outcomes in the mathematics field, the *5 Practices for Orchestrating Productive Mathematics Discussions* (Smith & Stein, 2011) lays out a model of instruction that provides "teachers with some control over what is likely to happen in the discussion as well as more time to make instructional decisions by shifting some of the decision making to the planning phase of the lesson" (Smith & Stein, 2011, p.7). In this model the 5 practices are (2011):

1. Anticipating – Teachers anticipate how they believe students will respond to cognitively demanding tasks based on their knowledge of the students and context.
2. Monitoring – Teachers monitor how students actually interact with the demanding tasks.
3. Selecting – Based on the monitoring, the teachers select students' work they think will be important to share with the rest of the class.
4. Sequencing – Teachers order the work/students they have selected in a meaningful way
5. Connecting – The teacher makes clear connections from the work presented to underlying or key ideas.

Key to the success of this model is that the teacher focuses on the work associated with anticipating during the planning of instruction. By thinking through the many different permutations of possible student responses to tasks, the teachers are able to prepare questions and other instructional moves to help focus students' attention on the underlying mathematical ideas; they are not simply giving the students answers that result in the task's demand being lowered or the discussion ending. Related to this anticipating and planning is the idea that teachers should think ahead about possible sequences for the students' work. This gives the teachers some advanced preparation for how they want the discussion to unfold and can even allow them to plant certain ideas that will allow for productive engagement in the task and discussion.

2.3.3 5 Practices for Orchestrating Productive Task-Based Discussions in Science

Using this framework from the mathematics filed, Cartier and colleges have transformed the five practices from the mathematics context to the science context (Cartier, et al., 2014). This transformation was not without difficulties, as the 5P for mathematics model does not overlay perfectly onto science education. The main difficulty in making this transformation arises from the fundamental differences in how mathematics and science think about tasks. In mathematics, tasks are thought of as occurring around any mathematical idea and stand-alone as addressing that individual concept. Mathematics tasks are usually structured in a way that students are only engaging with them over the course of a single lesson. This is not to say that multiple tasks in a sequence cannot cover the same idea, just that individual tasks typically only last for a single lesson.

On the other hand, science tasks are thought of existing in three separate categories: Experimentation tasks, Explanation tasks, and Data representation, analysis, and interpretation tasks (Cartier, et al., 2014). These tasks categories were chosen as fitting well with the various parts of the learning cycle. The learning cycle is an empirically studied instructional approach widely used in science education that utilizes 3, 5, or 7 steps in allowing students to construct knowledge (Lawson, 1989; Marek & Cavallo, 1997; Lawson, 2001) The learning cycle allows for teachers to design lesson arcs. These lesson arcs usually involve a number of different activities in which students will engage. The key principle is that throughout the entire lesson arc, the students are addressing the same underlying conceptual idea that builds on the pervious lesson’s materials in order to move forward in the arc. This means that within a learning cycle students may engage with a number of different science tasks, all building towards developing an understanding of a single underlying idea. This differentiation from mathematics is critical for thinking about creating tasks appropriate for the various parts of science lesson arcs. In Figure 3 the 5-step learning cycle is shown including where tasks from the three categories could be inserted into this structure.

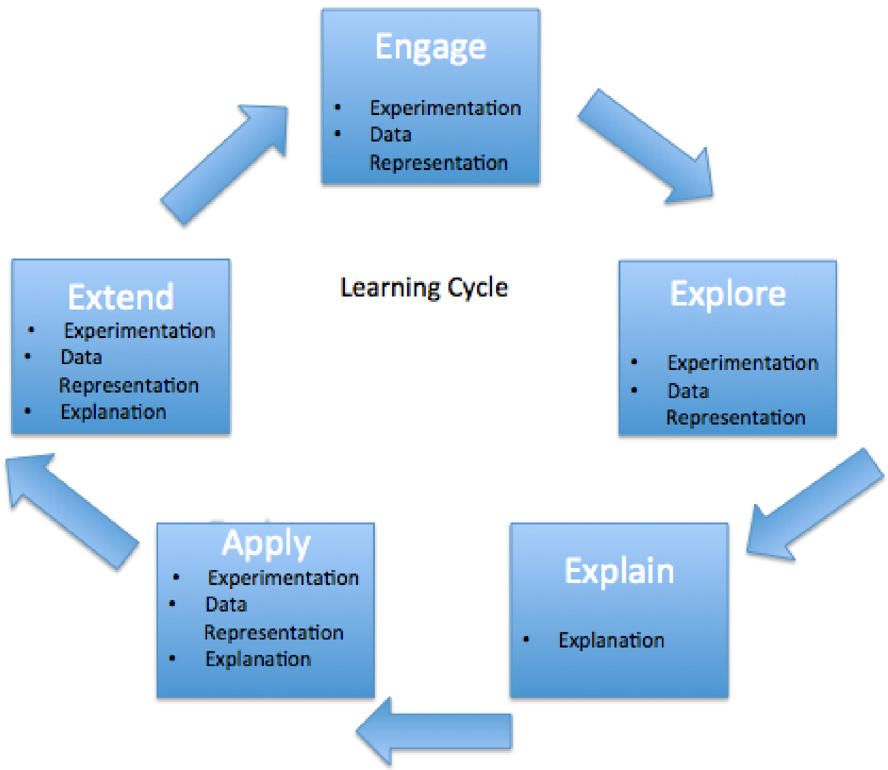


Figure 3. 5 Step Learning Cycle with Task Categories

The 5 practices for science (Table 3) are exactly the same as for mathematics: anticipating, monitoring, selecting, sequencing, and connecting (Cartier, et al., 2014). However, the science 5P model also stress two additional "pre" practices. The first of these is identifying the instructional goals of the lesson. These goals include learning goals (goals that explain what the students will *know* at the end of the lesson) and performance goals (observable student outcomes). The second is selecting a task. In the 5P model teachers select "instructional tasks that (a) provide students with opportunities to learn key science ideas while also engaging in important disciplinary practices; and (b) are robust enough to support a productive whole-class discussion following students' engagement in the task" (Cartier, et al., 2014, p.16). These two "pre" practices give a direct link for the PSST back to the NGSS in two ways. First, the NGSS outlines content learning goals and a sequence for such content over the course of students' K-12 schooling. Second, the reference to "disciplinary practices" points to the NGSS SEPs discussed earlier in this chapter. In looking at these practices we see that the 5P model has strong links to the view of engaged science learning outlined previously.

Table 3. Science 5 Practices

Practices	Descriptions
Identifying instructional goals (pre)	The teacher must identify the instructional goals for the students to achieve. Having clear goals allows for the selection and maintenance of tasks that aim to support the goals.
Selecting a task (pre)	The teacher must select (or more likely) modify high cognitive demand task(s) from the various resources they have at their disposal. The task should engage students in SEP and must directly serve the learning goals of the lesson.
Anticipating	Teacher anticipates how they believe their students will respond to the cognitively demanding task(s) based on their knowledge of the students, content, and context. This includes anticipating how students will respond to the task(s), one another, and the teacher.
Monitoring	Teachers monitor how students actually interact with the demanding task(s). This usually includes using a monitoring tool developed in the planning process to help keep track of students ideas and actions as they engage with the task(s) and interact with one another.
Selecting	Based on the monitoring, the teachers select students' work they think will be important to share with the rest of the class. From the anticipating the teacher should already have an idea of what pieces they want to select, however, during the monitoring they may come across student ideas the believe will contribute to the development of the underlying scientific ideas from the learning goals.
Sequencing	Teachers order the work/students they have selected in a meaningful way in order to facilitate a productive and coherent discussion. Again, from the anticipating, the teacher should have some idea of what this sequence will look like ahead of time. Sequencing ideas in productive ways based on what is dictated by the context, students, and content is critical in order to build student consensus and understanding.
Connecting	The teacher makes clear connections from the work presented to underlying or key ideas. This final step is critical so students do not walk away from the discussion with misconceptions.

In asking PSST to engage in the work of using the 5P model, we are also asking them to try to engage students in ways that draw students' attention to the underlying scientific ideas. This can be a difficult undertaking for both novice and expert teachers alike. One of the difficulties for PSST is allowing students to focus on the desired scientific ideas and not superfluous distractors that draw their attention away from the desired work. For example, a student trying to understand the relationship between pressure and volume of a gas in a closed system may have a set of data they are asked to look at and develop a relationship with. The student realizes they need to create a graph; however, they struggle with developing correctly spaced axis values. The student spends 15 min thinking about how the data should be spaced on the graph paper rather than using that time to look at what the data mean in relation to the pressure and volume relationship.

Researchers have thought about issues such as this in terms of Cognitive Load theory (Sweller, 1994; Paas, Renkl, & Sweller, 2003; de Jong, 2010), which postulates that students have very limited capacity in their working memory in order to satisfy current goals. As a result of this limited capacity in students' working memory, we need to limit the load we put on them during instruction in order for them to focus on the desired work. Based on Cognitive Load Theory, a solution to the problem of a student perplexed by graphing data would be to simply give the student a previously prepared graph and ask them to analyze it. The problem that arises with such a move is that it diminishes the students' ability to engage with many of the SEP's outlined by the NGSS. The question becomes how can PSST plan instruction that allows their students to engage with science content and SEPs while not adding too much cognitive load. One possible solution comes from technologies.

In following up with the pressure and volume example from above, if we have the students use a graphing program that solves the data spacing issue for them, we are still having them engage with the data, as the SEPs would suggest we should, while limiting the load on their working memory necessary for them to focus on the underlying relationship and what this means for gas molecules. If we do not leverage technology appropriately, we risk funneling students' attention and time to work that is not cognitively demanding in relation to the science content. The issue often raised when technology is not used to support high demand 5P lessons is "Where do students spend their time and energy?" When trying to orchestrate cognitive demanding tasks, PSST often fall into the trap of having students focus on the wrong things, like the graph scale. Using technology gives access to ideas and focuses student work in ways that are desired while still cognitively demanding.

It is important, however, to realize that not all technology is created equal. As previously discussed, technologies come with different sets of affordances and constraints. PSST need to utilize their understanding of several key variables when evaluating, selecting, and planning with technologies: the cognitive demand of the task they are asking the students to engage with, the underlying science learning goals, the context, and the students themselves. In other words, PST need to act as instructional engineers, utilizing their PDC for technology in order to plan engaging science instruction.

2.4 SUMMARY

This work hopes to make a unique contribution to the field by taking a different look at technology. As outlined, I am not arguing for the inclusion of technology simply for technology's sake. I am arguing for the development of PSST capacity to plan with and use technology because it addresses a very specific issue faced by many teachers, novice and expert alike, how to support students' engagement in learning science content. This work leverages technology as a resource to support the work of demanding tasks and instruction that is simply not possible without putting to use the affordances of technology in classrooms.

In the next chapter I explain how the Grossman et. al. framework and 5 Practices model were enacted in the PSST preparation program. Further, I elaborate on how the simulation and technology components of this project were integrated into the pedagogy course sequence. Finally, I provide details on how the data for this study were collected and analyzed.

3.0 METHODOLOGY

In this chapter I give an explanation of the course sequence and PSST makeup of the MAT and MOSAIC program that was the focus of this study. This is followed by a detailed explanation of the lesson sequence and intervention structures used in the PSST pedagogy course. From this account I detail the data that was collected, the sequence of that collection, and the research questions that the data were used to answer. As a reminder the five research questions being investigated are:

I. How do PSST think about and try to use technologies in their instructional planning prior to program intervention?

II. Following intervention, what do PSST attend to (e.g. affordances and constraints, modeling ability, etc.) around the use of computer simulations in their planning?

   a. In what ways do the dimensions of planning that PSST learned earlier in the program relate to the way that they plan with computer simulations?

III. How do contextual factors impact the way in which PSST plan for lessons involving computer simulations?

IV. Do the PSST attend to the same or different considerations when planning lessons involving computer simulations compared to lessons involving other digital technologies?

V. Do PSST demonstrate patterns or changes in their planning around digital technologies over time?

In the final section of this chapter I explain how the data are coded, managed, and represented in order to answer the above questions.

3.1 PARTICIPANTS & GENERAL PROGRAM CONTEXT

Each of the six PSST in this study completed undergraduate training in a science field prior to enrollment in formal teacher preparation (2 chemistry majors, 1 general science major, 2 biology majors, 1 physics major). Over the course of this study, four of the PSST (Table 3.1) participated in a one-year post-baccalaureate Masters of Arts in Teaching (MAT) program to obtain certification in a secondary (grades 7-12) science discipline (e.g. Biological Science, Chemistry, Physics, or General Science).

Table 4. PSST pseudonyms, internship information, and program affiliation

Name	Placement (Course level)	Content Area	Program
Courtney	Large urban district (academic)	Chemistry	MAT
Jay	University affiliated lab school (General)	Middle School - Physical Science	MAT
Gwen	Economically disadvantaged suburban district (academic)	Biology	MAT
Janet	Suburban (General)	Middle School – Physical Science	MOSAIC
Alice	Suburban (Honors)	Chemistry	MOSAIC
Tom	Large urban district (Honors and AP)	Physics	MAT

The other two PSST (see Table 4) in this study were enrolled in a one-year post-baccalaureate Master of Special Education with Academic Instruction Certificate (MOSAIC) program. The MOSAIC program spanned four semesters (Summer II, Fall, Spring, Summer I) and like the MAT program ended with certification in a secondary science discipline. Regardless of program, the six PSST were enrolled in the same pedagogy course sequence during the 2014 - 2015 school year. All of the PSST also participated in a 10-month internship in which they ramped up their teaching responsibilities over the course of the fall semester. This "phase-in" culminated with PSST having full responsibilities for one of their mentor teacher's courses by the middle of the fall semester (Table 5).

Table 5. PSST Fall Phase-in Schedule

Weeks	Description
1-5	• PSST work to build positive relationships with their mentor teacher and students • PSST are expected to be part of the planning process for the mentors' courses but are only asked to assist with or co-teach a handful of lessons • PSST are expected to reflect on both instruction and classroom contexts
6-9	• PSST transitions to take on full responsibility for one of the mentor teachers' classes this includes planning, teaching, providing feedback, tracking students progress and communicating with parents. • PSST are expected to be part of the planning process for the mentors' other courses but are again only asked to assist with or co-teach those courses • PSST are expected to participate in all department and school related staff development
10-13	• PSST continue the same work from weeks 6-9 • PSST are expected to get involved in a extra-curricular or non-academic activity
14-18	• PSST work to build positive relationships with their mentor teacher and students • PSST are expected to be part of the planning process for the mentors' courses but are only asked to assist with or co-teach a handful of lessons

Although the internship "phase-in" occurred over a number of months, the PSST pedagogy courses began with an intensive "jumpstart" in the first two weeks of the fall term. This jumpstart was intended to provide an opportunity for PSST to engage in early field observations in order to investigate the context of the instructional institution in which they were placed for their internship. The PSST placements ranged from urban to suburban school districts, included high and low SES students, and included middle and high school settings. PSST were asked to explore school and community issues, philosophies and beliefs about teaching, and learning strategies at their specific placement. After two weeks, the intensive jumpstart courses gave way to a more traditional class structure that lasted through the remainder of the fall, spring, and summer terms. Over the course of the MAT and MOSAIC programs PSST were exposed to a number of courses that encompassed teaching pedagogy, equity in education, educational research, special education, adolescent development, and health and wellness workshops (ATP) (see Table 6). The data collection for this study centered on the pedagogy course sequence PSST complete in the jumpstart and fall term, specifically Teaching & Learning in Secondary Science 1 & 2.

Table 6. PSST Course Sequence

	Term			
	Jumpstart	Fall	Spring	Summer
Course	Teaching & Learning in Secondary Science 1	Teaching & Learning in Secondary Science 2	Teaching & Learning in Secondary Science 3	Research Seminar
	Teaching Students with Disabilities in the Secondary Classroom	Teaching Students with Disabilities in the Secondary Classroom	Literacy, Assessment and Instruction for Students with Disabilities	Internship in Secondary Science
	ATP 1	Practicum in Secondary Science 1	ATP 2	
		Practicum in Secondary Science 2	Disciplined Inquiry	
		Teaching English Language Learners	Internship/Seminar in Secondary Science	

3.2 PEDAGOGY COURSE CONTEXT AND SEQUENCE

3.2.1 Overall Goals

Using a set of increasingly authentic (closer to the work of real classroom instruction) experiences the PSST engaged with and enacted "decomposed" planning practices in the pedagogy courses. This design choice allowed for the courses to be responsive to the Grossman et al. framework while supporting the 5P model (Grossman et al., 2009; Cartier, et al., 2014). The resulting *Teaching & Learning in Secondary Science 1 and 2* (pedagogy courses) sequence was designed to give PSST exposure and/or practice –

- implementing a model of engaged science learning and appropriate instructional strategies,
- building a positive classroom culture,
- establishing norms and routines,
- fostering positive professional relationships,
- planning for demanding instruction, and
- using technological resources effectively

The course syllabi of the two pedagogy courses are provided in APPENDIX A. In order to achieve the learning goals associated with the above practices, the courses were structured around leveraging the NGSS science and engineering practices (SEPs) through the 5 practices for discussion framework (NGSS Lead States, 2013; Cartier, et al.) and grounded in the idea of PSST as instructional engineers. In other words, PSST were implicitly and explicitly encouraged to think of themselves as engineers who are responsible for designing instructional episodes by using and adapting the resources and knowledge available to them, including technology.

Specifically, the PSST were required to engineer opportunities for their students to engage in high demand tasks that were supported through discussions with the goal of engaging the students with the NGSS SEPs.

3.2.2 Engaged Science Learning

PSST started the pedagogy course sequence with a set of activities that required them to engage as *learners*. These early activities enabled the PSST to recognize key features of tasks that serve to engage learners in authentic science practices, to identify some of the ways in which instructors support students engagement in these tasks, and to make inferences about the preparation required in order to design and support these types of learning opportunities. These early activities allowed the pedagogy course instructors to articulate program-level expectations related to *engaged science learning*. Specifically, PSST learned that they would be expected to engage secondary science students in high cognitive demand tasks that required them to think deeply about specific science phenomena. Moreover, PSST were expected to design opportunities for students to participate in science and engineering practices as part of this cognitive engagement. These activities were the PSST first exposure to the terminology and expectations of high cognitive demand tasks as starting points for instruction.

One goal of these activities was to develop an understanding in the PSST that most tasks in curricular materials are not initially designed to be high cognitive demand. As a result, these activities established that PSST would typically need to pull on multiple resources (textbooks, district curricula, lab manuals, internet resources, technology) in order to design such tasks. A second reason for facilitating these activities was to push the PSST to actively adapt them, in other words, plan in distributed improvisation fashion (Forbes & Davis, 2010). This distributed improvisation way of planning is most aligned with the idea of PSST as instructional engineers and fits with the model of task development and implementation put forward by the 5P model, which is leveraged later in the course sequence.

Following this set of activities the PSST engaged in a set of lessons that established the types of classroom norms and expectations necessary to foster instruction based around high cognitive demand tasks. In this sequence of lessons PSST first acted as learners before reflecting on possible ways to establish norms and routines equitably in their own placement sites. The choice to have them act as learners allowed for the PSST to have a common shared experience in order to ground class discussions. This was necessary since most PSST had only limited exposure to high demand tasks, or that terminology, prior to the course sequence.

Once these program-level views of learning were established they were grounded in current national standards documents (NGSS and Framework) and state teaching requirements. These program level views were then situated within the concept of curricular ideologies (how people think about the purpose of teaching, how this is associated with various instructional and assessment approaches, and how students learn in these various settings) (Schiro, 2012). Ultimately this sequence of lessons ended with a discussion around the history of science education (deBoer, 1991). The purpose of this particular sequence was to help the PSST build an understanding of how the science education community arrived at its current state and to make some connections between types of instruction and their historical significance in the scope of society. Establishing this historical background allowed for a class discussion of why the science and engineering practices from NGSS seem to be appropriate given the current academic and societal landscape. Throughout these discussions and activities, PSST developed an understanding of how various factors potentially influence how people (including their colleagues in their internship sites) think about “good” instruction and the overall goals of schools, and how these individual views might impact their own work as instructional engineers.

3.2.3 5 Practices Instructional Model Intervention

In the final set of lessons leading up to the integration of technology intervention, PSST participated in a set of lessons and assignments that decomposed the practices associated with planning a 5 practices task-based class discussion. In these lessons PSST were first introduced to the 5 practices for orchestrating productive discussion in a science classroom (5P) (Cartier et al, 2014). PSST were expected to engage in activities that demonstrated the two pre-practices (selecting learning goals and tasks) and 5 instructional practices (Anticipating, Monitoring, Selecting, Sequencing, and Connecting) put forward by the model (2014). Since each one of these practices can be difficult for novice teachers, each practice was decomposed into individual lessons for the PSST to gain experience at engaging in this type of work. A lesson in this context was part of a whole class period devoted to that topic or idea. Lessons lasted in length from 10-90 min and encompassed a wide array of activities including note taking, group lesson planning, role-playing, and whole class discussions.

The PSST were first asked to engage with the decomposed practice of anticipating. During anticipating, PSST were asked to plan, in great detail, how they expected their students would engage with a particular task or problem. The work of anticipating goes beyond simply talking about misconceptions students may bring to the lesson. This work includes thinking about prior knowledge and how the specific students in the class will bring that knowledge to bear during the discussion. It also includes anticipating the order in which students will address ideas or challenges, different ways they may approach the work, and how they will engage with group members or the class. On a general level, when PSST anticipate discussion, they imagine the discussion unfolding and plan ways (such as questioning, use of marking tools, etc.) to productively steer the talk toward target learning goals. To give PSST experience in this very difficult work, in a way that did not overwhelm or intimidate them, they engaged in a highly scaffolded lesson.

In this lesson PSST engaged in planning work. The PSST already had a classroom context (7^{th} grade life science class), a set of learning goals, and a high demand task that their students would engage with (APPENDIX B). The PSST had to anticipate "how students would engage with the problem" in small groups (2-3 people). After approximately 20 min of work time the PST participated in a whole class discussion around the types of anticipating they did, how different students might engage with different tasks, and where typical failures in anticipating this type of discussion often occur.

This lesson on anticipating was followed by a lesson on monitoring, in which the PSST participated in a planning and role-play activity (this time situated in the context of kinetic molecular theory) (APPENDIX C). The instructor for the course acted out two different classroom tasks and discussions while the PSST played the role of 10^{th} grade chemistry students. The PSST were asked to notice the types of monitoring and questioning that occurred between the "teacher" (the pedagogy course instructor) and "students" (the PSST) in the two scenarios. After a discussion around what the PSST noticed and the importance of monitoring and creating a tool that helps to facilitate the work of guiding a classroom discussion, the PSST, working in small groups, created a monitoring tool. The PSST were asked to consider the questions they might need to ask their students in order to keep the discussion on track, how they would keep track of important information surfaced by different students, and other ideas they thought might be important while monitoring a task. In both of these lessons the practices discussed were decomposed into work that was done in groups and, for a vast majority of the class, in a context outside of their content area. This allowed the PSST to have common interactions around the work of planning that fosters opportunities to gain shared experiences and build sense making of the 5P planning process (Ross, 2014).

In the final lesson that focused on the 5P, PSST were instructed to plan and enact a micro-teaching lesson in front of the pedagogy class in groups of two. Similar to previous lessons, the PSST were given a context, learning goals, and task for the lesson that they had to teach. Specifically, the PSST were asked to teach a lesson that was meant for 10^{th} graders who were utilizing models to explain phenomenological patterns – SEPs Developing and Using Models and Constructing Explanations. This time the PSST had to plan and orchestrate the discussion themselves. This micro-teaching assignment required the PSST to utilize the knowledge gained about planning (anticipating student and teacher interactions) from previous lessons and forced them to do the work of selecting, sequencing, and connecting during the class discussion. This micro-teaching work allowed the PSST to gain experience engaging in these planning and instructional practices in a way that provided for feedback from peers and opportunities to reflect on the practices using shared experiences whiles still doing so in a low risk environment. This lesson provided the PSST with several chances to engage with their classmates around how to improve the enactment of the various practices while at the same time experiencing issues that may not have otherwise surfaced in their own placement setting.

Pulling on the lessons from across the entire 5P model intervention, along with the historical and social frame presented early in the pedagogy course sequence, allowed for an easy transition to a discussion centered on the importance of technology. This discussion included ideas on how technology could be leveraged in order to meet the goals of engaging students in cognitively demanding tasks. The transition to talking about technology focused on the PSST ability to recognize the power of technologies to support engaging learning by providing opportunities for students to engage with ideas, representations, and data that would not otherwise be possible (Bell and Smetana, 2008). The series of lessons that followed this discussion allowed for the development of PSST knowledge and practices designed to leverage technology in support of planning engaging science learning rather than inserting technology just for its own sake.

3.2.4 Technology Intervention

Due to the nature of the technology intervention, mainly that it was an integrated part of the pedagogy course sequence and not a stand alone course, the way in which PSST engaged with planning, implementing, and thinking about technology was critical to the development of their planning practices. These planning practices were necessary to leverage technology as a way to support engaging science lessons. To support the development of the knowledge, skills, and practices associated with planning using technology as a resource to support engaging instruction, the pedagogy course intervention unfolded over a four-week period and consisted of two specific in-class interventions and several assignments.

To begin with, in order to provide the PSST with some specific practices associated with the use of technology in instruction and at a level they could understand as novices, several key practices were decomposed a priori. The first of those practices revolved around computer or Internet simulations. Computer simulations are often defined as “computer-generated dynamic models that present theoretical or simplified models of real-world components, phenomena, or processes" (Bell and Smetana, 2008, pg.23). Most computer simulations differ from traditional curriculum materials in that they are usually created to "stand-alone." The developers did not create them to be situated among other resources and they are often void of any specific instructional intent outside of accurately modeling the phenomena of study.

Due to the fact that simulations are not typically situated among other resources, teachers have difficulty understanding their instructional possibilities. Despite this limitation, the use of computer simulations in classrooms have been linked with positive outcomes associated with enhanced conceptual change in constructivist instruction (Windschitl & Andre, 1998), providing access to inquiry type activities (diSessa, 2000; Linn & His, 2000), and engaged exploration (Adams, et al., 2008)

Although simulations have been linked with these positive outcomes (Smetana & Bell 2012), each one has its own set of affordances and constraints (i.e. ability to visualize the general paths of molecules vs. accuracy of molecular collisions, or standardized variable intervals vs. how easy it is to see dosage patterns) that play a role in shaping how PSST can craft learning episodes around them (Podolefsky, Perkins, & Adams, 2010). In fact, the products of students work with simulations can vary widely and can include collecting data, supporting claims/ideas, building new knowledge, exploring new ideas, confirming hypothesis, just to name a few, all of which fit nicely onto the 3 types of tasks (Experimentation, Explanation, and Data representation, analysis, and interpretation) outlined in the *5 Practices*.

The pedagogy course intervention around simulations began with the PSST engaging as learners with a kinetic molecular theory (KMT) simulation in a lesson orchestrated by the instructor (APPENDIX D). During this lesson the instructor modeled practices associated with good use of technology for engaging students in high cognitive demand tasks and discussion.

Specifically, the instructor gave the PSST a data collection and analysis task that required them to answer a specific question around molecular motion. The instructor then monitored, questioned, selected, and sequenced specific groups to share their ideas about KMT with the class. During the sharing of ideas the groups were directed to point out where in the simulation (which was projected on the front board) their data came, what they noticed about it, and why they thought it was important. After the activity was completed the instructor facilitated a group discussion about how the KMT simulation allowed for the structure of the task to be presented in this specific structure. The discussion focused on allowing students to use and see multiple forms of representations to show a phenomena that is not actually visible.

The second part of this lesson involved the PSST being exposed to thinking about the learning affordances and constraints of a different simulation. PSST were given a specific context, learning goals, objectives, and a simulation to look at, all of which were closely aligned with the early 5P lessons. PSST were asked to think about the goal of the lesson and decide how students might engage with the new simulation, what positive things the simulation could do for improving student learning, and any problems that could or would arise by using this simulation in the given context. At the end of the lesson the class discussed the importance of evaluating technology for affordances and constraints given the context in which they are planning and the content they want the student to learn. To close the lesson, the instructor made explicit connections between affordances and constraints and the lesson on the KMT simulation from earlier in the course. In making the thinking explicit around the planning the instructor enabled the PSST to make connections and ask questions about how this planning might look different in their individual settings. Ultimately this gave the PSST an opportunity to see how these affordances and constraints might be leveraged or managed in a learning sequence. At the end of this lesson sequence PSST were asked to go out and integrate a simulation into their placement site instruction. They were instructed to make explicit the choices they made and why they did so in their lesson plans. Throughout this pedagogy course intervention the PSST engaged in a number of decomposed practices including:

- Leveraging Affordances associated with the learning goals and objectives
- Minimizing the constraints and distractions to the LG and objectives
- Selecting simulations that are a good mix of affordances and constraints
- Constructing tasks with simulations
- Engaging students with the simulators in productive ways
- Anticipating student interactions with the simulators

Having the opportunity to go out and engage in planning with simulations, the PSST came back to the pedagogy course and participated in a lesson that moved the thinking from the specific simulation context to the broader category of digital technologies. This general technology lesson built on the ideas of affordances and constrains to support learning goals while focusing on the work of building the capacity to plan. In this lesson, PSST first revisited the planning they did for their simulation lesson and had a discussion around their own reflections on that process and how it might be improved. Next, the PSST engaged in the small and large group discussion in which they were asked to consider what the lesson planning process for using general digital technology should look like, factors they needed to consider, and practices they needed to leverage in that process. The PSST answers and ideas were then compared and contrasted to the factors, practices, and ideas developed during the simulation lesson activity.

The PSST were then asked to create a list of as many digital technologies related to instruction in school that they possibly could. From this list the PSST selected a resources they believed they would be able to use in their placement and described the affordances, constraints, and possible ways the technology could be used in a short presentation to the class. The purpose of the discussion that ensued was to allow the PSST to see the diverse set of resources that exist across the different placements and how they might be used in different contexts. Throughout this lesson on general digital technology resources PSST engaged in a number of decomposed practices including:

- Leveraging Affordances associated with the learning goals and objectives
- Minimizing the constraints and distractions to the LG and objectives
- Selecting technology resources that are a good mix of affordances and constraints
- Constructing tasks that utilize the power of digital technologies to maintain cognitive demand

Across the technology lessons in the pedagogy course the PSST were able to develop an understanding of the landscape they were required to navigate when planning and carrying out engaging instruction with technology. The goal of this was to allow the PSST to see the benefits of using technology to mitigate certain contextual and content factors as they plan engaging science instruction while building their capacity to plan lessons using these practices.

3.3 DATA COLLECTION

Data collection occurred while the PSST were enrolled in their two pedagogy courses in the jumpstart and fall semesters of 2014 along with a single day of data collection on the first day of the spring 2015 semester. Across the top of Figure 4 you see the outline of the four major themes and 11 lesson topics covered over the course of the jumpstart and fall semester in chronological order. The bottom portion of Figure 4 shows when in relation to the themes and lessons in the pedagogy courses each piece of data were collected. As an example, the Curricular and site resource survey and pre TPACK survey were administered between the lesson on NGSS and Demanding Tasks during the Engaged Scientific Learning portion of the pedagogy course sequence.

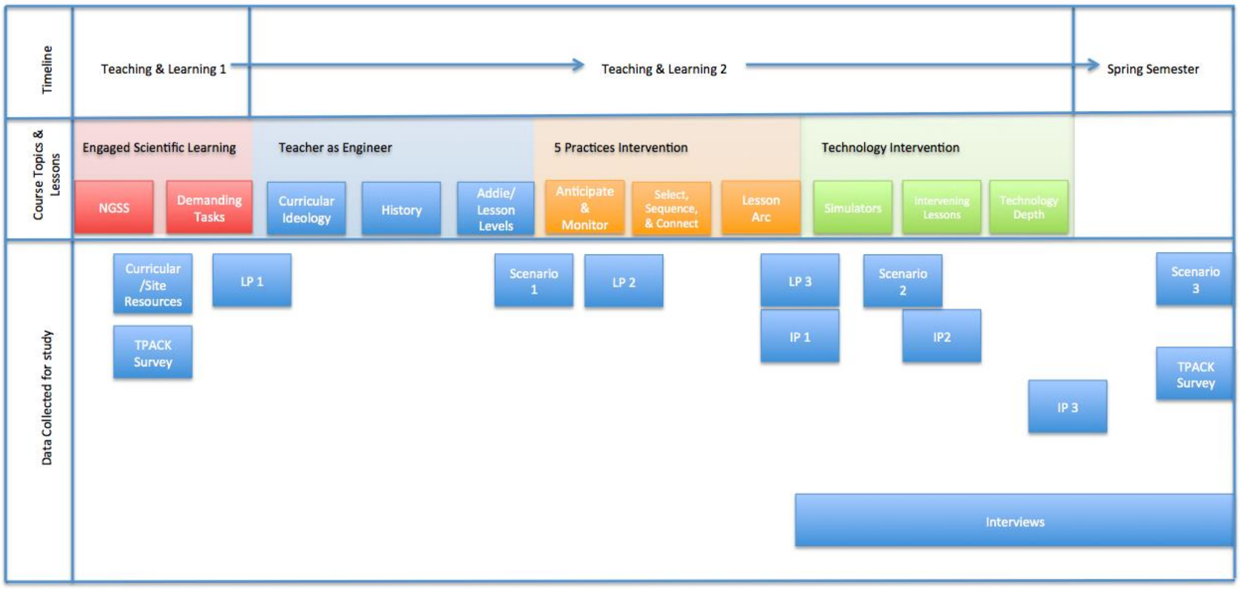


Figure 4. Outline of Major Topics & Lessons Covered in the Pedagogy Course Sequence

3.3.1 Technology Based Curricular & Site Resources Assignment

As seen in Figure 4, the PSST technology based curricular and site resources assignment was the first piece of data collected. This course assignment (APPENDIX E) asked students to catalog and describe various technological resources that existed at their placement site along with possible curricular resources that were technologically based. In Chapter Four this data provides insight on the impact internship resources have on PSST initial ability to plan with technology and how that context can play a role in PSST planning with technology.

3.3.2 TPACK Survey

Immediately following the 5P instructional intervention the PSST TPACK survey (APPENDIX F) was administered (pre-TPACK). This same survey was administered the first day of the spring semester (post-TPACK). This instrument is an adapted version of a tested and verified measure used in elementary science education (Schmidt et al., 2009; Perkins & Scott, 2014). In their original work Schmidt and colleagues administered the survey to a set of preservice elementary teachers (Schmidt et al., 2009). The purpose of the survey was to see elementary perservice teachers' growth along the seven TPACK dimensions (Table 7) from the beginning of their program until the end.

The survey has been adapted by replacing general elementary content statements with secondary content statements specific for each of the content areas of the PSST (Chemistry, Biology, Physics, and General Science). This survey provides a self-report measure of the seven knowledge dimensions (Table 7) considered important in the TPACK framework. For each statement the PSST can respond as strongly disagree (1 point), disagree (2 points), neutral (3 points), agree (4 points), strongly agree (5 points).

Table 7. TPACK Knowledge Components and their Descriptions

Knowledge Component	Description
Content Knowledge (CK)	Teachers' knowledge of the content matter they are expected to teach in their class.
Pedagogical Knowledge (PK)	Teachers' knowledge of the process of teaching, including all the practices and interactions that go into that process.
Technological Knowledge (TK)	Teachers' knowledge of how to use and understand various technologies.
Pedagogical Content Knowledge (PCK)	Teachers' content knowledge that is specific to the practice of teaching in relationship to making the material accessible and learnable to students.
Technological Content Knowledge (TCK)	The way in which technology knowledge and content knowledge come together to create new practices in the content field.
Technological Pedagogical Knowledge (TPK)	How the use of different technologies impacts the practice of teaching and learning.
Technological Pedagogical Content Knowledge (TPCK)	The basis of effective teaching with technology as it represents the integration of all three knowledge pieces for the purpose of creating engaging learning opportunities.

The results of this survey showed each of the PSST self-reported strengths and weaknesses along all seven TPACK dimensions (Table 7). This allowed for the exploration of emergent patterns between these self-reported dimensions and PSST ability to plan. The results of the pre-TPACK survey were used as part the set of cases that aimed to look at how PSST thought about their planning prior to pedagogy course intervention. The pre-TPACK and post-TPACK survey data were used to look at how students self-reported dimensions of TPACK changed over pedagogy course sequence.

3.3.3 Simulation Scenario Assignment

Three times throughout the pedagogy course sequence (prior to the 5P intervention, after the simulation intervention, and the first day of the spring semester) (Figure 4) the PSST were given a simulation scenario assignment (APPENDIX G). Each of these assignments consisted of a written scenario specific to the primary content area of the individual PSST. Each scenario consisted of a set of contextual factors (grade level, class level and length, technology availability), learning goals, objectives, and a screen shot and url link to a computer simulation. The content presented in the simulation was always closely aligned with the learning goals and objectives of the scenario. Along with the scenario, each assignment contained five identical questions (Figure 5).

1) Given the context information provided evaluate the Affordances of this simulation to achieve the learning goal.

2) Given the context information provided evaluate the Constraints of this simulation to achieve the learning goal.

3) Assuming you are required to use this simulation by your mentor teacher, explain what you will ask the students to do and why. (Remember you may use the simulation in any way you see fit)

4) What if any materials would you provide the students. You don't need to actually cerate the materials just describe what they are.

5) Describe what kinds of interactions are going to occur. These can be interactions between students, teacher and student, student and materials.

Figure 5. Simulation Scenario Questions

The purpose of these scenarios was to limit the context and outside variable that the PSST have to attend to when thinking about planning to utilize simulations in instruction. This focused the PSST attention to the simulation part of the planning. The ultimate goal of the simulation scenario tool was to gain a direct measure of PSST pedagogical content knowledge, technological content knowledge, technological pedagogical knowledge, technological pedagogical content knowledge (Table 7) and planning practices associated with simulations void of the other confounding variables (learning goal, student ability, resource availability). Other survey instruments, specifically those developed using the TPACK framework, do not address specific planning, rather they address self-reported efficacies around planning or use observation protocols to assess TPACK in classroom instruction (Schmidt et al., 2009; Harris, Mishra, & Koehler 2009). This simulation scenario tool allowed for the evaluation of how PSST think about individual technologies under certain constraints so that their knowledge for planning with technology could be explored in greater depth.

Two separate forms (A and B) (APPENDIX G) of the tool were created for each of the PSST primary content areas. The first assignment used form A and was administered after the teacher as engineer section of the pedagogy course was completed. The answers to this scenario gave baseline information to the way the PSST were thinking about simulations prior to pedagogy course intervention. The second simulation scenario assignment used form B and was administered after the PSST finished the pedagogy course simulation intervention (described in section 3.2.4). This scenario showed PSST knowledge and planning practices just after intervention and acted as a mid-point in the PSST learning trajectory across the pedagogy course sequence. The final simulation scenario used form A and was administered in the first week of the spring semester after the PSST had completed the final general technology instructional performance (described in greater detail below). This post scenario captured how PSST were thinking about planning with technology after they had completed the intervention and been given other instructional topics to focus on during their planning (e.g., Literacy in the content, Formative and Summative Assessment) in the pedagogy courses. From previous work (Ross, Kessler, & Cartier, 2014) we know that often times, the PSST ability to think about new practices shifts their attention away from previously established practices in negative ways. Therefore the purpose of this final simulation scenario was twofold. First, to see if the PSST retained the planning practices around technology previously addressed in the course sequence. Second, if a dramatic drop in the use of these practices in the lessons/instructional performances was because the PSST were unaware of the practices they should be utilizing or because they had shifted their focus to new practices, unrelated to technology, that were addressed in the course sequence. This scenario tells some of that story by removing many of the other barriers and just focusing PSST attention on planning practices associated with simulations.

3.3.4 Lesson Plan Assignments

Over the pedagogy course sequence, three lesson plan assignments were collected for analysis. In general, the lesson plan assignments were meant to provide the PSST with opportunities to engage in the work of planning lessons in a low stakes, highly supportive environment. Although each of the three lesson plan assignments were submitted for grades in the pedagogy course, none of these required the PSST to enact the lessons at their internship site.

The first lesson plan assignment (Lesson Plan 1) (APPENDIX H) was collected just after the PSST had finished their work on engaged science learning. Although this lesson plan had little to do with the PSST use of technology, the first lesson plan provided valuable information about how the PSST thought about their context, students, and curricular materials while they were lesson planning. This provided background information on how the PSST planned tasks early on in the pedagogy course sequence.

The second lesson plan assignment (Lesson Plan 2) (APPENDIX I) was collected after the PSST had engaged in the teacher as engineer section of the course and half way through the 5P lesson sequence. In this assignment PSST had to plan to engage their students in a lab while engaging them in a high cognitive demand task in support of engaged science learning. This lesson plan provided information about the PSST abilities to think about their work as instructional engineers and the practices they used in planning high demand tasks.

Finally, the PSST submitted lesson plan assignment three (Lesson Plan 3) (APPENDIX J) prior to the PSST engaging with the intervention around simulations. This lesson plan was the first time the PSST had been instructed to think explicitly about technology while still considering the other factors of engaging learning. This lesson plan provided information on the initially planning practices that PSST utilized when planning engaged science learning supported with technology.

3.3.5 Instructional Performance Assignments

After each of the major pedagogy course interventions (5 Practices, Simulation, and General Technology) described in section 3.2.3 and 3.2.4, the PSST were given an instructional performance assignment. Each of these instructional performance assignments required the PSST to plan a lesson, implement that lesson at their internship site, collect evidence (supervisor and mentor feedback) from the lesson, and write a reflection. The lesson plans associated with these instructional performance assignments were a way to probe PSST planning practices and instructional decisions for a given lesson while they took into account the specific contextual factors that had to be addressed at their individual internship sites.

Instructional Performance 1 (APPENDIX K) required PSST to plan a lesson around the integration of a 5P discussion and took place just after the Model that Promotes Engaged Learning & Teachers as Engineer section of the pedagogy course. Instructional Performance 2 (APPENDIX L) had the PSST plan a lesson that integrated a simulation into their classroom instruction and took place just after the PSST finished the simulation intervention. Finally, Instructional Performance 3 (APPENDIX M) had the PSST plan a lesson that integrated a digital technology of their choosing.

In combination, the lesson plan assignments and instructional performance assignments also provided an opportunity to explore the PSST knowledge domains. In the lesson plans for both these data PSST were expected to explain how they were using different pedagogical, technological, and content approaches to plan engaging instruction. Table 8 shows how data were collected for each PSST on their individual knowledge dimensions. The table lists all the various knowledge dimensions from the TPACK framework on the left. On the top of the table are the various data that allow for analysis of the knowledge dimensions. The table cells indicate the type of measure associated with that dimension for that data. If the cell is left blank that data does not allow for an evaluation of that knowledge dimension. A question mark indicates that the data may or may not be available depending on the PSST choices in planning.

Table 8. TPACK Dimension Data Collection

Dimensions	TPACK Survey	Simulation Scenario Tool	Lesson Plan 1	Lesson Plan 2	Lesson Plan 3	Instructional Performance 1	Instructional Performance 2	Instructional Performance 3
Content Knowledge	~~Self Report~~		~~?~~	~~?~~	~~?~~	~~?~~	~~?~~	~~?~~
Pedagogical Knowledge (PK)	Self Report		Direct	Direct	Direct	Direct	Direct	Direct
Technological Knowledge (TK)	Self Report				Direct		Direct	
Pedagogical Content Knowledge (PCK)	Self Report	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Technological Content Knowledge (TCK)	Self Report	Direct			Direct		Direct	Direct
Technological Pedagogical Knowledge (TPK)	Self Report	Direct			Direct		Direct	Direct
Technological Pedagogical Content Knowledge (TPCK)	Self Report	Direct			Direct		Direct	Direct

An assumption of this work, and the larger teacher education program in which this study is situated, is that each of the PSST have extensive content knowledge. This assumption is based on the fact that each PSST earned a four year undergraduate degree in science major. Based on this assumption, that content knowledge component was not a focus of this work and has been struck in the Table 8.

Looking across the lesson plans, instructional performances, and the TPACK measures allowed for the interrogation of the planning practices and knowledge dimensions the PSST leveraged as they designed instruction.

3.3.6 Interviews

Finally, one-on-one interviews around the PSST Lesson Plan 3 assignment and Instructional Performance assignments were conducted throughout the semester. The interview protocol (APPENDIX N) was structured in such a way that the questions are meant to be asked about specific choices that the PSST made in their lesson plans and instructional performances. Through these interviews, the PSST thinking around their use of resources was probed for understanding in relation to the instructional goals they hoped to achieve and connections made to resources from curriculum, placements, or outside sources. Each of the six PSST were interviewed for 15-30 minutes after each Instructional Performance over the course of the study. This gave a distribution between the assignments in case one or another happened to elicit better response from the PSST. This resulted in a more complete data set that provided insight into the various factors at play in the PSST lesson planning along with giving some insight into how the PSST planning changed over the course of the study.

3.3.7 Surveying the Data

All consenting PSST (n=6) work was collected and pseudonyms assigned before the written materials were scanned or downloaded and stored on a secure drive for later analysis. Across the top of Table 9 are all of the data sources for this study. An X marks the research questions that this data helped to answer and multiple Xs in a single row show sources of data that were used to either triangulate results or build sets of cases to answer that research questions.

Table 9. Sources of Data to Answer Each Research Question

Research Question	Curricular & Site Resource Assignment	TPACK Survey	Simulation Scenario Assignments	Lesson Plans	Instructional Performances	Interviews
1	X	X	X	X	X	X
2	X	X	X		X	X
3	X				X	X
4			X		X	X
5		X	X	X	X	X

The data were analyzed using various sets of rubrics (discussed in section 3.4) to create cases and examples designed to answer many of the research question. As Yin points out "a case study is an empirical study that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomena and context are not clearly evident"(2002, pg.13). As the variables of the PSST internship, program intervention, and other factors are all intertwined, this research is well suited for such methodology. In this study multiple sources of evidence were collected in order to build an understanding of how the phenomena of preparing teachers to plan instruction and leverages technology was impacted by their preparation program and outside context. As discussed in chapter 2, many of the data collection, and contextual pieces, have a grounding in research and learning theory, which is another feature associated with strong case study work (2002).

Using these various data types allowed for both a within-case and cross-case analysis. The within-case analysis allowed for a descriptive explanation of the factors and pieces that went into PSST successfully and unsuccessfully planning for using technology in engaging instruction. Each of these within-case analyses looked in-depth at each PSST experiences and growth over time along with trying to build an explanation of what impacted that growth or lack thereof.

When considering the cross-case analysis, Miles and Huberman suggest that there are two purposes (1994). The first is generalizability. Using a "case-oriented" analysis for this research allows for the building of rich cases that incorporate various contextual and resource variables into descriptions that have the potential to build understanding of what pieces need to be in place, and why, for students to successfully develop the skills necessary to plan for using technology in engaging instruction. Second, using cross case analysis gives the opportunity to look for possible explanatory variables associated with positive and negative cases of success in using planning for technology. In the following sections I explain how the analysis of each data type were conducted.

3.4 DATA ANALYSIS

3.4.1 Technology Based Curricular & Site Resources Assignment

This assignment was used to create a set of descriptors for each PSST around the types of technological and curricular resources each district and classroom had at their internship site. After building the cases from other data sources, patterns were explored between site and curricular resources and planning practices with technology.

3.4.2 TPACK Survey

PSST responses to the likert scale survey were compiled for the pre and post survey. First, each PSST individual responses were tallied to create a profile for each PSST. This was created using a count of the number of response that fell into the categories of positive (scores of 4 or 5), neutral (score of 3), or negative (score of 1 or 2). Next, each individual code was connected with its associated TPACK dimension. This allowed each PSST to be assigned an individual score on each dimension. Along with calculating individual PSST dimension scores; the question data were also averaged across PSST to create pre and post dimension scores (including calculation of standard deviations). These values were used to determine if the PSST dimensions scores fell in, above, or below one standard deviation of the group mean.

3.4.3 Simulation Scenario Assignments

PSST submitted three separate simulation scenario assignments over the course of the study, as described earlier in chapter three. These scenarios were coded using a set of codes designed to assess responses on the various levels of the TPACK knowledge components built into the scenario tool (Appendix P). Question 1 (affordances), 2 (constraints), and 3 (tasks) were coded along four TPACK dimensions (pedagogical content knowledge, technological pedagogical knowledge, technological content knowledge, and technological pedagogical content knowledge) as shown in (Appendix P). Question 4 (description of resources) was coded using the same levels, but only along one dimension, level of explanation of task resources. Question 5 (description of interactions) was coded on the same TPACK dimensions as the previous questions, however, the codes were dichotomous, (0) for non and (1) for any. Finally, the dichotomous variable of offloading was assigned, (0) for offloading to the materials and (1) for not offloading.

The individual TPACK and question dimensions were coded for each PSST. These individual PSST dimension scores were combined to provide a single (total SSR) score for each

PSST. The total SSR scores were averaged across PSST to provide a single score for each scenario in order to graph and interrogate the average change on the simulation scenarios over time.

In order to establish reliability a second coder coded 30% of the PSST scenario responses. The secondary coder was trained on the codebook (APPENDIX P) using a simulation scenario 1 assignment that had not been randomly selected for second coder scoring. Based on the reliability formula in Miles and Huberman (1994) the interrater reliability was calculated to be 68%. In subsequent conversations with the second coder, any individual disagreement was discussed and consensus reached.

3.4.4 Lesson Plan Assignments

Over the course of the study the PSST submitted 3 lesson plan assignments. All of the lesson plans were coded along 7 dimensions; launch, tasks, 5P work time, technology resources, Technology work time, TPACK, and close. A set of codes (APPENDIX O) was used to code each lesson plan for various planning practices. These codes were developed across two iterations of previous research designed to assess students' use of 5P discussions in planning (engaged science learning) and from a pilot study of this research (technology with high demand tasks) (Ross, Kessler, & Cartier, 2014; Kessler & Cartier, 2014). Although two of the lesson plan assignments were not directly related to planning with technology they were still coded on all dimensions not associated with technology in order to provide baseline information about how PSST think along these dimensions of engaged science learning.

To give an example of how the codes were assigned, Figure 6 shows Courtney's full Lesson Plan 3 assignment. In Figure 6 are boxes labeled with the lesson plan dimension –

planning practice – and assigned level with an arrow that point to the portion of the lesson used to code that specific dimension. (Note: each of the codes for task, maintenance of demand, TPACK and supporting materials look across the entire lesson plan or a handout document that was attached as separate files in order to assigning a code. These codes were not included in the example.)

Introduction to VSEPR Theory

Date: 11/5/14	**Grade:** 10	**Time Length:** 43 minutes

Big Idea:
- VSEPR theory is a model used to predict the geometry of individual molecules.

Learning Goals:
- There is a difference between electron geometry and molecule geometry for molecules.
- Nonbonding electrons (lone pairs) are not shared with another atom and are found in the outmost electron shell of atoms. They play a role in the electron geometry of a molecule.
- Bond angles change with different structures of molecules.

Objectives:
- Students will be able to accurately determine electron geometry and molecule geometry for molecules using VSEPR theory.
- After exploring the model, students will be able to explain the role that nonbonding electrons pairs play in determining molecular geometry.
- Students will be able to predict bond angles correctly for different molecules.

Standards:
CHEM.B.1.4.1
Recognize and describe different types of models that can be used to illustrate the bonds that hold atoms together in a compound (e.g., computer models, ball-and-stick models, graphical models, solid-sphere models, structural formulas, skeletal formulas, Lewis dot structures).

Materials:

For all groups:
- Computer with internet access
- Website link

For individual student:
- Simulation handout

For teacher:
- Lesson plan
- PowerPoint presentation with warm-up question
- Extra copies of handouts

Safety Concerns

- This lesson does not have an immediate danger in safety since we are not in the lab.
- Students should be sitting with group, but if they get up, they should walk in the classroom to avoid accidents.

Set Up:

- There is a sign on the regular classroom door to go to the 3rd floor computer lab to serve as a reminder from yesterday's class that we are in the computer lab today.
- A copy of the lesson plan is printed and set on front table (for reference, if needed).
- Copies of the simulation handout are printed and ready to hand to students as they enter the room.
- The folder where weekly warm-up papers are placed are on the front table in the computer lab and students are told where to find their sheet for the warm-up activity.
- Warm-up question is already shown on the PowerPoint presentation as students enter the classroom.
- Students will be working with their assigned lab groups.

Launch – motivates students to participate – No mention

Lesson Opening (7 minutes)

Students know to grab their paper for the weekly warm-up questions when they first enter the room. Since we are in a different environment, I will tell students where to find it so they can begin their warm-up that is already on the board.

The question of the day is:
Draw Lewis structures of the following molecules: H_2O, CH_4, BF_3, SF_4

After 4 minutes after the late bell rings, I will have some students come to the board and draw their models. I will also ask for them to explain how they figured out how many electrons are in th[e] drawing and how they figured out how many bond there were.

Launch - Connection to Previous work - Inadequate

I expect students to understand how to draw the structures of the molecules since we have been working on them for the past two days. If a student does not understand how to draw it and they drew it on the board, I would have another student help them understand where they went wrong in their representations. Common mistakes could be doing their math wrong, not realizing that hydrogen does not follow the octet rule, and not putting the lone pairs on the molecules that need them.

Launch – communicates the purpose of the task - Inadequate

Launch (6 minutes)

- I will tell the students (alongside the PowerPoint presentation)
  - We are going to be looking at a new way to look at molecules.
  - With your partner(s), you will have a chance to explore how these models receive their names and angle bonds, as well as seeing how nonbonding electrons play a role in molecule geometry.
- Next, I will show the simulation on the SmartBoard and go over certain features, such as how to add an atom, where they can find a lone pair, adding/removing options, as well as the two

Launch – communicates instructions on using the technology – adequate

Launch – communicates the expectations of the task – adequate

views they can look at (model and real molecules).

- I will then put the lab partner groups up again on the board, so students know who they are ...g with.
- ...ve 25 minutes to complete this activity and complete up to task 5. Task 6 will be used as homework.

Technology Resources – Affordances – Adequate

Activity Time (25 minutes)

- Students will take the first few minutes of the activity time to sit next to their lab partner(s) and find the website (written on their lab handout).
- This is the first time the students are seeing the VSEPR model, so I expect there will be questions about how this model works.
    - Reason for using this simulation first is because it can be difficult for students to think in three dimensions. If they only see the arrangement on paper, it is hard to see the angles, as well as how the atoms are arranged. By seeing the model first in 3-D, the students will have a better idea of arrangements when only using paper in the next few days to come.
- Since there is a lot of exploring in this model, I will be cautious of students just playing around with the simulation rather than trying to find the concepts of the VSEPR model. This is the downfall when using a simulation. Students may just play with the model or go online to other websites rather than try to figure out this model.
- Below are an idea of some misconceptions I believe students will have when using th... theory simulation.
- Misconception 1:
    - There is no difference between electron pair geometry and molecular geometry.
    - To address this misconception, there is a question in the worksheet I want students to answer to make sure they understand there is a difference.
        - If students do not see there is a difference, I will help them in the simulation and ask them to play with lone pairs and bonding. I will also make sure they have the "molecular geometry" and "electron geometry" boxes checked to see the difference.
        - When the students are exploring this concept I will ask, "what happens when you add a lone pair?" For example, if the student already had three bonds to the central atom and added a lone pair, I expect the student to think that the geometry would change because something new was added. I would then tell them to look at the different names in the geometry portion of the simulation. Here, the molecular geometry is trigonal pyramidal and the electron geometry is tetrahedral. I would then ask the students, "why do you think the names are different." If the students do not know, I will remind them to think about the prefix and how the bonds are around the central atom. With this information, I think the students will see that there is a difference between the two and that the molecular geometry gives th... structure of the atoms and the electron pair geometry is determined f... total electron pairs.
- Misconception 2:
    - If you change if a single bond is double or triple, it will change the molecular geometry.
        - While this may seem like it would change something, it does not. I would

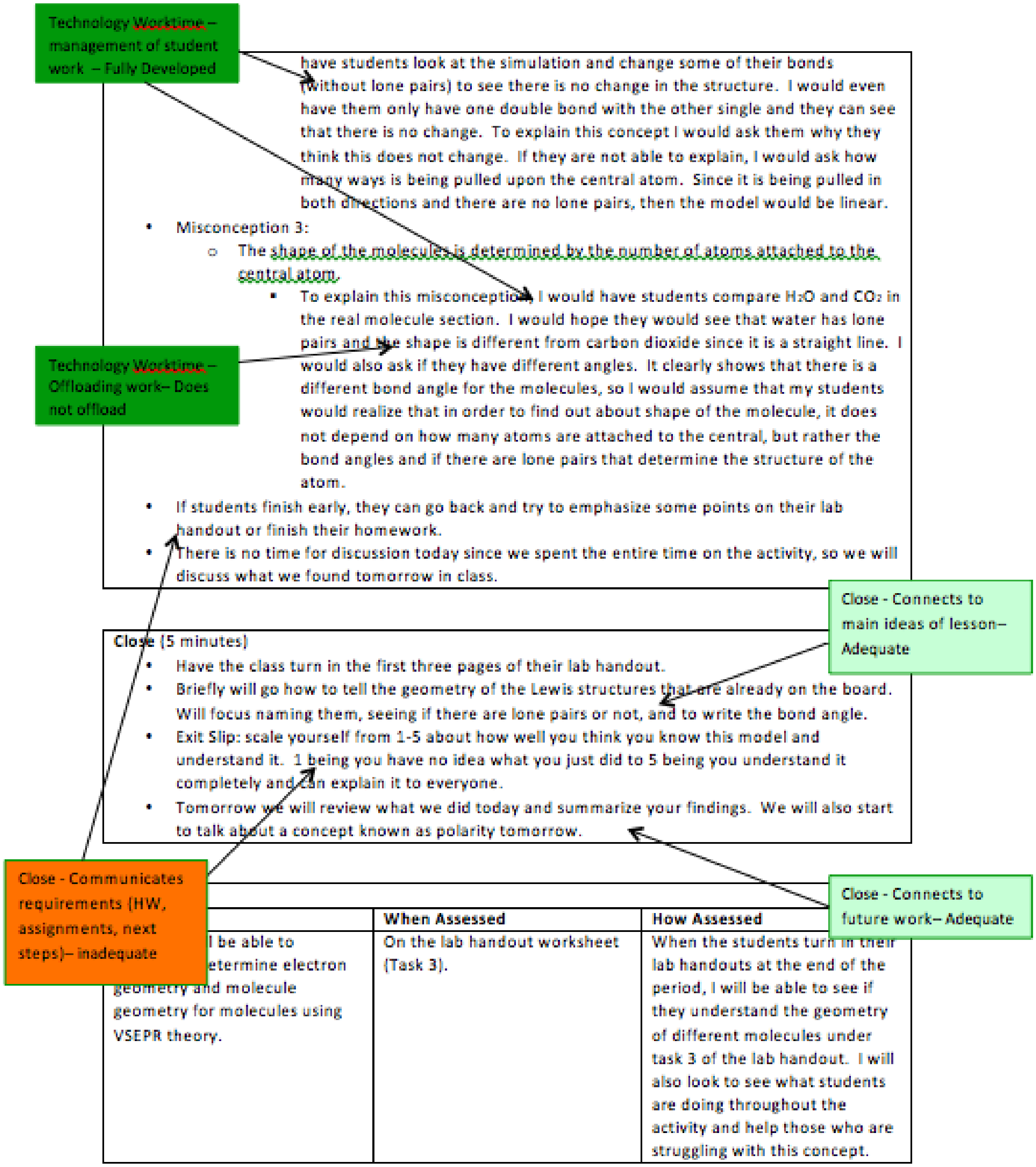
Worktime - Supporting Task: Connection to the learning goal – Inadequate

Technology Resources – Constraints – Adequate

Worktime - Supporting Task: Anticipating – Adequate

Technology Worktime – Engagement with Technology – Fully Developed

Worktime - Supporting Task: Anticipating – Adequate



have students look at the simulation and change some of their bonds (without lone pairs) to see there is no change in the structure. I would even have them only have one double bond with the other single and they can see that there is no change. To explain this concept I would ask them why they think this does not change. If they are not able to explain, I would ask how many ways is being pulled upon the central atom. Since it is being pulled in both directions and there are no lone pairs, then the model would be linear.

- Misconception 3:
  - The shape of the molecules is determined by the number of atoms attached to the central atom.
    - To explain this misconception, I would have students compare H_2O and CO_2 in the real molecule section. I would hope they would see that water has lone pairs and the shape is different from carbon dioxide since it is a straight line. I would also ask if they have different angles. It clearly shows that there is a different bond angle for the molecules, so I would assume that my students would realize that in order to find out about shape of the molecule, it does not depend on how many atoms are attached to the central, but rather the bond angles and if there are lone pairs that determine the structure of the atom.
- If students finish early, they can go back and try to emphasize some points on their lab handout or finish their homework.
- There is no time for discussion today since we spent the entire time on the activity, so we will discuss what we found tomorrow in class.

Close (5 minutes)

- Have the class turn in the first three pages of their lab handout.
- Briefly will go how to tell the geometry of the Lewis structures that are already on the board. Will focus naming them, seeing if there are lone pairs or not, and to write the bond angle.
- Exit Slip: scale yourself from 1-5 about how well you think you know this model and understand it. 1 being you have no idea what you just did to 5 being you understand it completely and can explain it to everyone.
- Tomorrow we will review what we did today and summarize your findings. We will also start to talk about a concept known as polarity tomorrow.

	When Assessed	How Assessed
...l be able to ...etermine electron geometry and molecule geometry for molecules using VSEPR theory.	On the lab handout worksheet (Task 3).	When the students turn in their lab handouts at the end of the period, I will be able to see if they understand the geometry of different molecules under task 3 of the lab handout. I will also look to see what students are doing throughout the activity and help those who are struggling with this concept.

Figure 6. Courtney's Coded Lesson Plan 3

Each of the individual practices was assigned a single score. All of the practice scores for a given dimension were combined to give a single dimension level score for each of the students. These scores were then averaged across all of the students to assign average dimension scores for each of the coded lessons. The dimension scores for each individual student were also combined to give an overall lesson plan score for each student. The total student scores were also used to create average lesson plan scores, which were used to create graphs that demonstrated group and individual growth over time. Assigning scores in this way allowed for many different levels of analysis within and across the different PSST and lesson plans.

After coding was completed a second coder was trained on the LPR codebook (APPENDIX O) using a Lesson Plan 3 assignment that had not been randomly selected for second coder scoring. Twenty-two percent of the lesson plan data was coded by a second coder and using the same reliability formula described in 3.4.3 the interrater reliability was established at 63%. Through follow-up conversations with the second coder any discrepancies in the data were resolved.

3.4.5 Instructional Performance Assignments

PSST submitted three instructional performances over the course of the study with two of those focused on technology-based lessons. These instructional performances consisted of packets created from work completed at their placement site and contain formal lesson plans, resources used, examples of students' work, and reflections on the lesson. Each of these Instructional Performance lessons plans was coded using the same coding strategy as the individual lesson plans (APPENDIX O).

Just as with the lesson plan data, 22% the instructional performance data was coded by a second coder and interrater reliability established to be 64%. Again, through subsequent conversations with the second coder, any individual disagreement was discussed and consensus reached.

3.4.6 Interviews

While the interviews were being conducted extensive notes were taken and the conversations recorded. Following the completion of the data collection for the study I went back and listened to each recording. Again notes were taken on relevant responses made by the students. Finally, using these notes as a guide, I listened and partially transcribed relevant sections that had been identified as having significance related to aspects of planning and or context associated with PSST planning decisions. While transcription was done I marked the document with identifications of various planning practices, dimensions of planning on the LPR, and contextual factors along with identifying the prompt that was given prior to the PSST responses (Table 10). These transcripts were used as evidence to build cases for research questions one through four. Quotes and general ideas from the interviews were also used to triangulate data from other data sources and used to explain specific aspects of PSST decisions about planning practices.

Table 10. General Transcript Identification Markers

Learning Goals > Technology	Technology > Learning Goals
Contextual Factors	Level of Demand
Support of Demand	Simulation Selection
Technology Selection	Affordances
Constraints in planning	Planning Difficulty
Classroom Norms	Engage
Explore	Explain
Apply	Offloading to Curriculum
Offloading to Technology	Task Demand
Focus of planning	Student Prior Knowledge
CK	PK
TK	TCK
PCK	TPK
TPACK	Designing task
Designing Materials	

4.0 RESULTS

In this chapter I report the results of the data analysis described in Chapter Three used to answer the research questions in this study. The chapter is organized into five sections, each addressing the five different research questions. Section 4.1 addresses Research Question 1 and discusses PSST planning and knowledge prior to the pedagogy course intervention. Along with the general assignment data, this section includes in-depth cases for each of the six PSST. Section 4.2 addresses Research Question 2 and highlights the four planning routines that emerged from the data. Section 4.3 addresses Research Question 3. Examples of PSST context and its impact on planning are also included in this section. Section 4.4 addresses Research Question 4 and revisits how the PSST leveraged the planning routines discussed in section 4.2. Finally, in section 4.5 I address Research Question 5. This section includes data that bridges the entire study and focuses on what can be understood about PSST development over time.

4.1 RESEARCH QUESTION 1: HOW DO PSST THINK ABOUT AND USE TECHNOLOGIES IN THEIR INSTRUCTIONAL PLANNING PRIOR TO PROGRAM INTERVENTION?

4.1.1 Pre TPACK self-assessment assignment

During one of the last class sessions in the Teaching & Learning 1 pedagogy course the PSST spent 15 minutes completing the Likert scale based TPACK self-assessment assignment. All of the PSST completed the assignment, although the assignment did not actually count for a course grade.

The values reported in Table 11 are the average responses across each of the statements associated with that dimension. The n shown in the bottom of the first column represents the number of items used to obtain that score. A score above 3 is considered a positive response, with higher scores representing a more positive self-report. A score of 3 is considered a neutral response. A score below three is considered a negative response, with lower scores representing a more negative self-report.

Table 11. Pre-TPACK Self-Assessment Average Dimension Scores for Each PSST

Dimension	Description	Symbol	Courtney	Jay	Gwen	Janet	Alice	Tom
Technological Knowledge n= 7	The ability to use and understand technologies	TK	3.71	3.43	2.86	3.43	3.86	4.14
Content Knowledge n= 4	Knowledge of the content matter	CK	4.75	4.25	4.25	4.00	4.75	4.00
Pedagogical Knowledge n= 7	Knowledge of the process of teaching	PK	3.57	3.43	2.29	4.14	3.43	3.43
Pedagogical Content Knowledge n= 3	Ways of representing and formulating the subject matter in order to make it comprehensible to others	PCK	4.5	3.50	3.25	3.50	3.00	4.75
Technological Content Knowledge n= 4	Way in which technology and content come together to create new practices or knowledge.	TCK	4.5	3.25	2.5	3.25	2.25	4.00
Technological Pedagogical Knowledge n= 5	How the use of different technologies impacts the practice of teaching and learning	TPK	3.6	4.40	2.6	4.20	3.20	4.20
Technological Pedagogical Content Knowledge n= 8	The basis of effective teaching with technology" as it leverages all of the knowledge dimensions together	TPACK	4.0	4.13	2.13	3.50	2.00	4.50

All of the PSST had strongly positive responses to the content knowledge dimension of the assessment. All but one PSST, Gwen, had positive responses on the dimensions of technological knowledge, pedagogical knowledge, and technological pedagogical knowledge. PSST had mostly positive responses with some closer to neutral on the dimension of pedagogical content knowledge. Finally, the dimensions of technological content knowledge and technological pedagogical content knowledge had strong positive responses from Courtney, Jay, Janet, and Tom. At the same time these dimensions had negative responses from Gwen and Alice. Taken together, the overall responses were positive and indicated that the PSST overwhelmingly had a positive opinion of their own TPACK dimensions.

The values reported in Table 12 are a count of the total number of positive, neutral, and negative responses given by each student across the 39 statements posed on the pre TPACK self-assessment. Alice had the most evenly distributed responses to the TPACK assignment. Courtney, Janet, Tom and Jay (although to a slightly lesser extent) all had primarily positive responses. Gwen was the only PSST who had primarily negative responses.

Table 12. PSST Positive, Neutral, Negative Response Count to Pre-TPACK Self-Assessment

	Courtney	Jay	Gwen	Janet	Alice	Tom
Positive	31	26	9	28	15	32
Neutral	8	11	11	8	10	6
Negative	0	2	19	3	14	1

Looking across the results of the TPACK assignment, four of the six PSST overall responses on the assessment were positive. One PSST had a set of well-distributed responses (positive, neutral and negative). Lastly, one PSST had primarily negative responses. This early set of primarily positive responses is contrary to previous research that utilized a similar TPACK instrument (Schmidt et al., 2009; Perkins & Scott, 2014). In that work, all with undergraduate preservice elementary teachers, the pre-assessment scores were much more distributed and overall less positive. This contradiction could be the result of the small sample size in this study or it could be the result of having secondary level PSST who had already completed a bachelor's degree in science. Regardless, the results suggest that the PSST in this study had positive beliefs in their ability to teach their individual content using sound pedagogical practices that integrate technology in instruction from a very early stage in the pedagogy course sequence.

4.1.2 Pre technology assignments

In the first 8 weeks of the pedagogy course sequence, PSST became familiar with engaged science learning as it is described in the NGSS, the 5Practices for Task-Based Discussion model, and thinking of themselves as instructional engineers. During this time, PSST completed three key assignments: Lesson Plan 1, Lesson Plan 2, and Instructional Performance 1. None of these assignments required PSST to utilize technology in any way. PSST submitted Lesson Plan 1 and Lesson Plan 2 for feedback and grading in the pedagogy course, but did not implement these lessons in their internship sites. In contrast, completion of Instructional Performance 1 required planning a detailed lesson, implementing the lesson with secondary students at their internship site, and completing a detailed reflection.

Of the 18 individual PSST assignments submitted that did not include any specific requirements around integrating technology, only one PSST planned to use technology. The Lesson Plan 2 assignment required the PSST to plan a lab lesson. Tom took this opportunity to engage his students in a lesson on acceleration that utilized a set of lab probes, which were the primary source of data collection in his physics lab. Despite Tom’s choice to use technology in support of his lab activity, his Lesson Plan 2 assignment contained little evidence of supporting engaging instruction. In fact, his Lesson Plan 2 was indicative of a PSST who leveraged few planning practices, especially planning practices associated with technology. Given the early point in the pedagogy course sequence, and the fact that integration of technology had not been discussed at all in the sequence, these results are not particularly striking. However, given the overwhelmingly positive response on the TPACK assignment and the distributed time between individual assignments and the requirement of Instructional Performance 1 being taught at their internship site, the lack of technology use could be seen as signal that the PSST were not leveraging the technology available to them at their internship sites.

4.1.3 Technology based assignments prior to intervention

In the first 10 weeks of the pedagogy course sequence, prior to the beginning of the technology intervention, the PSST completed two key assignments that required, or were based on, the use of technology: Lesson Plan 3 and Simulation Scenario 1. Lesson Plan 3 did not require PSST to implement the lesson at their internship site, but did require them to submit the assignment for feedback and grading in the pedagogy course. The Simulation Scenario 1 was assigned to PSST during a Teaching & Learning 2 class period, which fell at the end of the teacher-as-instructional-engineer lesson sequence. PSST were given 48 hours to complete the questions on the assignment and email their responses back to the instructor. The Scenario was not graded as part of the pedagogy course and students were aware that this assignment was solely part of the research study they had agreed to be a part of earlier in the program.

In the following sections I report the results of PSST responses to the two class assignments that required them to think about and plan instruction that uses technology in support of engaged science learning along with data from Interview 3.

4.1.3.1 *Lesson Plan 3*

Using the Lesson Planning Rubric (LPR) (APPENDIX O), I evaluated each PSST Lesson Plan 3 assignment along seven dimensions (launch, task, 5P worktime, technology worktime, technology resources, TPACK, close) as shown in column 1 of Figure 7. Within each dimension I measured 2-5 specific planning practices. For example, within the Task dimension, I evaluated the initial level of Cognitive Demand (CD) for the task the PSST selected or designed, whether the task for the lesson used any Science and Engineering Practices (SEP) from the NGSS, and the extent to which the PSST offloaded the instructional work of the task to the curriculum materials they used for the lesson. The maximum points a PSST could earn on Lesson Plan 3 using this rubric was 71. Figure 7 shows the assigned codes using the LPR rubric for the Lesson Plan 3 pedagogy course assignment, including the total LPR score. Table 13 shows the simplified coding key for the LPR rubric. Note that the dichotomous categories, identified in column 2 of Figure 7 are simply red (0) for negative and green (1) for positive.

Table 13. Simplified LPR Code Key

	Not Mentioned	Inadequate	Adequate	Fully Developed
Code	0	1	2	3

		Courtney	Jay	Gwen	Janet	Alice	Tom
Launch	Connection to previous work	1	1	2	1	3	3
	Motivates student participation	0	0	1	0	0	2
	Communicates the purpose of task	1	1	1	3	3	2
	Communicates the expectations of the task	2	0	2	2	3	1
	Communicates instructions on using the technology	2	1	2	1	0	0
Tasks	Initial Level of CD (Dichotomous)	1	1	1	1	1	2
	SEP use (Dichotomous)	1	1	1	1	1	1
	Offloading work to curriculum materials (Dichotomous)	0	0	0	0	0	1
SP/General Worktime	Supporting Task: Anticipating	2	2	2	2	3	2
	Supporting Task: Questions	2	1	2	2	3	2
	Supporting Tasks: Materials	1	2	2	1	2	2
	Supporting Task: LG Conection	1	2	3	0	2	2
	Support of task demand across work time	0	0	0	0	0	0
Technology Worktime	Engagement with Technology	3	1	1	1	2	2
	Management of student work with technology	3	2	1	2	2	1
	Maintaining Demand	2	0	0	0	1	0
	Offloading work to technology (Dichotomous)	1	0	0	1	1	0
Technology Resource	Description of Affordances	2	2	0	3	0	0
	Description of Constraints	2	0	0	0	0	0
TPACK	PCK	3	0	3	0	2	2
	TCK	3	0	2	2	2	2
	TPK	3	0	1	1	0	2
	TPACK	3	0	0	0	1	2
Close	Connects to main ideas of lesson	2	3	2	1	1	2
	Connections to future work	2	0	2	2	1	0
	Communicates requirements (HW, assignments, next steps)	1	0	2	0	0	0
	Total	44	20	33	27	34	33

Figure 7. PSST Lesson Plan 3 LPR Scores

The data from Figure 7 demonstrate that the PSST all planned lessons that included the use of Science and Engineering Practices. The PSST also demonstrated the ability to write lesson plans that support students' engagement in instructional tasks by anticipating students' responses and planning questions. However, none of the PSST included supports that would function to maintain cognitive demand of tasks in the planning of their lesson worktime**.** The PSST also planned low demand tasks and often offloaded their instruction to the curriculum materials. In other words, the PSST would often plan to have student engage with a worksheet, experiment, or activity with the expectation that by students engaging with those curricular materials they would learn something without any additional support being needed from the teacher. This offloading was a recurring theme across the PSST Lesson Plan 3, with the lone exception of Tom. Despite the positive task result for Tom, he still only had the third best LPR score (33) for the assignment as his Lesson Plan Assignment 3 contained almost no planning related to the technology related dimensions of the LPR.

Finally, looking across the other dimensions and specific planning practices for Lesson Plan 3, the PSST demonstrated mixed results across the LPR dimensions, especially the technology dimensions. On each of the 11 planning practices related to technology, the PSST were at best split on their level of planning. In many instances, a single planning practice had three different codes across the 6 PSST. Given the early point in the pedagogy course sequence this distribution of ability levels in relation to written lesson plans is not all the surprising. The PSST had not participated in any coursework pertaining to technology and had only been in their internship site for a few weeks. As such, one might expect that PSST who had more experience or opportunities to engage with technology may have developed more abilities at this point than other students with less exposure. Another possible explanation is that the PSST were still developing the skill of writing lesson plans.

4.1.3.2 *Simulation Scenario 1*

All PSST completed Simulation Scenario 1 (APPENDIX G) within 48 hours of the assignment being assigned. Using the Simulation Scenario Rubric (SSR) (APPENDIX P), I evaluated each PSST Simulation Scenario 1 assignment and the results are reported in Figure 8. Questions 1 (affordances), 2 (constraints), and 3 (tasks) were coded along four TPACK dimensions (pedagogical content knowledge, technological pedagogical knowledge, technological content knowledge, and technological pedagogical content knowledge) as shown in Table 14. Question 4 (description of resources) was coded using the same levels, but on only one dimension, level of explanation of task resources. Question 5 (description of interactions) was coded on the same TPACK dimensions as the previous questions; however, the codes were dichotomous, (0) for none and (1) for any. Finally, the dichotomous variable of offloading was assigned, (0) for offloading to the materials and (1) for not offloading. This final code was assessed across all of the Simulation Scenario question responses.

Table 14. Simplified SSR Code Key

	No Sign	Minimal Knowledge	Some Knowledge	Adequate Knowledge	Strong Knowledge
Code	0	1	2	3	4

		Courtney	Jay	Gwen	Janet	Alice	Tom
Affordances	PCK	2	1	2	3	3	3
	TCK	3	4	2	3	0	3
	TPK	0	1	0	1	0	0
	TPACK	3	1	0	0	0	0
Constraints	PCK	3	3	3	4	2	3
	TCK	2	4	3	4	2	4
	TPK	0	0	0	3	2	0
	TPACK	2	0	0	3	2	0
Tasks	PCK	2	4	1	2	3	3
	TCK	0	4	0	1	0	3
	TPK	0	4	0	0	0	2
	TPACK	1	4	0	0	0	3
Description of Resources		2	3	1	2	1	1
Descriptions of Interactions (Dichotomous)	PCK	1	1	1	0	0	1
	TCK	0	1	0	0	0	0
	TPK	0	0	0	1	1	0
	TPACK	0	1	0	0	0	0
Offload (Dichotomous)		0	0	0	0	0	0
	total	21	36	13	27	16	26

Figure 8. PSST Simulation Scenario 1 SSR Scores

Overall, the PSST had stronger scores on dimensions of pedagogical content knowledge and technological content knowledge across the Simulation Scenario 1 questions. This connection between the pedagogy and the content suggests that the PSST are able to relate the content given to them in the learning goals with the pedagogical moves they might make. The high technological content knowledge score suggest that PSST are able to see how the various parts of the technology support students' development of the learning goals (content) in this scenario. However, low scores on both technological pedagogical knowledge and technological pedagogical content knowledge suggest an inability to connect the simulations with sound pedagogical instruction while thinking about how to plan engagement given the constraints of the scenario.

Jay and Tom were the only two PSST to score adequate or above on the technological pedagogical content knowledge portion of the task question. In this question the PSST were asked to be specific about the task they would have the students engage in using this simulation and why. Earning an adequate or above on this part of the technological pedagogical content knowledge demonstrates an ability of the PSST to make strong connections between the technology, pedagogy, and content in the task they have created for their students to engage. This is probably the most complex part of the planning process and demonstrating this knowledge suggests an advanced level of work considering Simulation Scenario 1 occurred prior to the pedagogy course intervention. Although Jay and Tom did score well on this portion of the SSR, they, along with all of the other PSST, made the choice to offload instruction and instructional responsibility to the simulation materials rather than planning explicit strategies to support students' learning while using the simulation.

Looking across the Lesson Plan 3 assignment and Simulation Scenario 1 assignment the PSST demonstrated an attention to planning practices [(1) supporting the use of science and engineering practices in their tasks; (2) anticipating students' responses to the task; (3) supporting questioning during the task] and a high level of knowledge associated with pedagogical content knowledge and technological content knowledge. This high level of knowledge associated with areas that involved content does not come as a surprise given the nature of the PSST undergraduate background.

What is of particular interest from this data is the disconnect between the PSST pre-TPACK assessment – showing primarily positive responses for planning and enacting instruction with technology – and their ability to demonstrate that skill in either the Lesson Plan Assignment 1 or Simulation Scenario Assignment 1. In fact, a clear pattern of failing to make links in the planning between the technology and the pedagogy was a major result. This suggests that despite having positive beliefs about their ability, at this early stage of their pedagogy course, the PSST were not able to show any such connections between technology and pedagogy in their planning.

4.1.4 Cases

Using data from the Pre-TPACK Self-Assessment, Lesson Plan 3, Simulation Scenario 1, and Interview 1 (focused on Lesson Plan 3), cases were created to highlight the various strengths and weaknesses of each PSST thinking and planning using technologies prior to the pedagogy course technology intervention. To organize the cases, they are presented in order of strength of planning as coded on the LPR for Lesson Plan 3, beginning with the strongest.

4.1.4.1 *Courtney*

Courtney completed her internship in a large urban district teaching mainstream chemistry students. She had a projector and smartboard in her classroom and access to a school wide computer lab. In her Pre TPACK self-assessment (Table 12), Courtney answered positively on 26 statements, neutral on 11 and negatively on 2 of the 39 total statements. Looking at her self-reported compiled knowledge component scores shows all positive responses with the strongest areas being content knowledge and technological pedagogical knowledge, 4.25 and 4.4 respectively (on a 5 point scale). This distribution of TPACK scores in combination with her strong LPR score (44 of 71 and 25 of 32 on the technology related sections) on her Lesson Plan 3 suggests she had some strong interest and ability to think about technology in her planning from the beginning of the pedagogy course sequence.

She showed an early understanding of how technology could have an impact on her students in the planning process. In Lesson Plan 3 Courtney planned a self described "engage learning cycle lesson" using a popular chemistry simulation that allows students to visualize various parts of the VESPER model, included their bond angles. Although she did a good job in her Lesson Plan 3 of writing explicitly about supporting students' use of the technology (Figure 9), Courtney's interview responses showed a limited understanding about making connections between the pedagogy, technology, and supporting students' learning of the goals by engaging in a high demand task.

- Misconception 1:
    - There is no difference between electron pair geometry and molecular geometry.
    - To address this misconception, there is a question in the worksheet I want students to answer to make sure they understand there is a difference.
        - If students do not see there is a difference, I will help them in the simulation and ask them to play with lone pairs and bonding. I will also make sure they have the "molecular geometry" and "electron geometry" boxes checked to see the difference.
        - When the students are exploring this concept I will ask, "what happens when you add a lone pair?" For example, if the student already had three bonds to the central atom and added a lone pair, I expect the student to think that the geometry would change because something new was added. I would then tell them to look at the different names in the geometry portion of the simulation. Here, the molecular geometry is trigonal pyramidal and the electron geometry is tetrahedral. I would then ask the students, "why do you think the names are different." If the students do not know, I will remind them to think about the prefix and how the bonds are around the central atom. With this information, I think the students will see that there is a difference between the two and that the molecular geometry gives the structure of the atoms and the electron pair geometry is determined from the total electron pairs.

Figure 9. Excerpt From Courtney's Lesson Plan 3 (supporting students use of the simulation)

Specifically, she seemed to feel that by directing students to complete particular tasks within the simulation, she would have ensured that they met the target learning goals related to understanding bond angles and molecular and electronic geometries:

> "I mean I tried to make it as high as I could. But I think with what, like, I think, like maybe more medium I guess. Um, just in the sense there are things I had to lay out of the

> things I wanted them to get out of it. But I mean ideally they're still the ones finding it on their own… But if they're like asking questions as to what is this what's that, like to have them sit down in a sense go though what is happening in the simulation. So it's like, ok, well if the question is more like what is happening with lone pairs, have them create a model that just has them connected to atoms and then you put in one with some lone pairs. So what happens to it, like, make sure that like everything is working. Like they have the bond angles or the box is clicked and the same thing to see the geometry so its not simple being like oh this is what it is but like making sure they are understanding what is happening in the simulation and like guide them to figure out the correct answer." (Interview 1)

In the previous quote from Interview 1 we see that Courtney was thinking about offloading much of the instructional work to the simulation she selected for the lesson. She expected that by students seeing the results from the simulation they would build some understanding of why they were getting the angels displayed by the simulation. This offloading does not allow for the support of student engagement with the technology. A better move would have been for her to help build student understanding by encouraging students to think about what they had previously learned about electron and atom repulsion and attraction and relate that to what they were observing on the screen.

In her interview Courtney also talks extensively about making sure the students have checked the right boxes without supporting what those choices represent in the simulation. This offloading of instruction to the technology and curriculum materials was a reoccurring trend in her lesson plans. In fact, she offloaded instruction to the materials in 4 of the 6 coded lesson plan assignments in the pedagogy course.

Finally, Courtney did not connect the technology and pedagogy in the Simulation Scenario 1, scoring only "some knowledge" on the SSR rubric on 1 of the 8 technological pedagogical knowledge or technological pedagogical content knowledge categories. The following excerpt (Figure 10) from Simulation Scenario 1 is her response to question 3, which asks the PSST to explain what they would ask their students to do with the simulation in the scenario and why. The response Courtney gives shows a broad connection to the learning goals, and an inability to make a connection between the technology and pedagogical choices she made.

Assuming you are required to use this simulation by your mentor teacher, explain what you would ask the students to do and why.

- I would use this an introduction to molarity and tell students to explore what will happen when you add more solute to the solution and what happens when you add solvent
    - This way students are able to explore the concept on their own and not listen to a lecture on what molarity is
    - They are also able to visualize some of these concepts
- I would inform students to not use the evaporation button since it does not work properly

Figure 10. Courtney's Response to Task Question on Simulation Scenario 1

Despite her strong LPR score on Lesson Plan 3, Courtney's overall data from her pre intervention assessments and interview suggest that Courtney was having a hard time leveraging good planning practices as she thought about planning engaging science instruction with technology for her chemistry students.

4.1.4.2 *Alice*

Alice was one of two PSST who were enrolled in a dual certification (science and special education) program. She completed her internship in a suburban high school teaching honors chemistry. Her classroom had its own dedicated laptop cart and a teacher computer with a projector. Alice had the most equally distributed responses on her Pre-TPACK Self-Assessment, with 15 positive responses, 10 neutral responses, and 14 negative responses. This distribution was also seen in her dimension scores, with two negative values (technological content knowledge-2.25 and TPACK -2.0), four positive values (technological knowledge -3.85, content knowledge – 4.75, pedagogical knowledge – 3.4, and technological pedagogical knowledge – 3.2) and one neutral (pedagogical content knowledge – 3.0)

Alice scored 34 of 71 points (11 of 32 on the technology dimensions) on the Lesson Plan 3 assignment. Although she did well in regards to not offloading instruction onto the technology, she did move a lot of instruction onto the curricular resources, mainly the handout. We see an example of this in the following excerpt from the launch portion of her lesson plan.

> *Launch:*
> *Those numbers are part of what we refer to as balancing the chemical equations. We are going to start working with these numbers today and exploring how equations are balanced. To do that, we are going to use a simulation using the laptops. (I will pass out the handout at this time). You will be working individually to explore the simulation and you will have 25 minutes to explore the simulation. On your handout, you will see some questions to answer, your responses to these questions will be due at the end of the period.* (Lesson Plan 3)

When Alice was asked about her planning to support demand during Interview 1 her response indicated limited understanding of how to best support this instruction:

> "Again, just encouraging students to manipulate things in the simulation instead of just quickly assuming that they can do it kind of thing. Or making sure that the students are working independently not just simply hearing what someone else says." (Interview 1)

Alice was one of three PSST who had no mention about the description of affordances in their Lesson Plan 3. Despite her lesson plan not showing much thinking around the affordances of the simulation, Alice talked about them extensively in her interview. In fact, she was the only PSST to talk about these affordances unprompted in Interview 1, saying:

> "I was really trying to think about what the simulation would allow the students to explore. The affordances of the simulation in terms of the different visualizations it gave of the different atoms and molecules. As well as a pictorial balanced representation so that they could see what it meant to actually change the coefficient." (Interview 1)

Later in the interview she again came back to affordances of the simulation saying:

> "PhET was best because many different visual representations about what is going on with coefficients instead of them just being numbers and then counting numbers. You can actually see things changing and what they correspond to." (Interview 1)

She showed limited offloading to technology in her Lesson Plan 3 assignment. Yet, in the following excerpt from her Simulation Scenario 1 assignment we see her choose to completely offload instruction to the technology:

> I will have the students work in partners with another student to facilitate their interaction and allow for two students to collaborate with the simulation and bounce ideas off of each other regarding the simulation. The student pair will interact collaboratively with the materials and each other. The teacher will serve as an elicitor/facilitator that will not be providing any direct instruction to the students and will allow the students to adequately explore the materials on their own. (Simulation Scenario 1)

Based on her pre intervention data, Alice showed some positive signs of attending to planning practices focused on technology to support engaged science instruction. Specifically she showed a very strong ability to think about and leverage the affordances of technology in the instructional decision related to content.

4.1.4.3 *Tom*

Tom, like Courtney, was a teaching intern in a large urban district. His placement included limited computer resources outside of a school computer lab and set of class lab probes. Unlike Courtney, his placement consisted of teaching mostly advanced and AP physics students.

Tom had the highest number of positive responses to his Pre-TPACK Self-Assessment with 32. Tom also had 6 neutral responses and 1 negative response with average dimension scores above 4 on every category except pedagogical knowledge (3.43). His distribution of TPACK, especially a lower pedagogy score, indicated an overall confident PSST, but one that still had some concerns about his knowledge of teaching pedagogy. This lack of teaching pedagogy manifested itself in Tom's early LPR scores. Tom scored only 11 and 14 out of a possible 43 points on the first two Lesson Plan assignments. These scores reflected a lack of planning practices focused on using pedagogical supports to engage students in tasks. By

Instructional Performance 1, Tom had begun to develop an understanding of how to improve his planning of engaged science instruction and he scored a 19 out of 43 on his LPR. By Lesson Plan 3, Tom started to show improvement in his ability to leverage planning practices focused on the task. Specifically, he was the only PSST to not offload work to the curriculum materials and require a high cognitive demand task for this assignment.

Tom chose to use a simulation of elastic and inelastic collisions for his Lesson Plan 3 assignment. For his lesson, Tom decided to engage his students in an interactive discussion around the simulation. In order to support his students in that work, and without offloading the instruction to the technology, Tom was explicit in his plans about how he would engage his students while anticipating how they might engage in the discussion around the simulation. In the following excerpt from his Lesson Plan 3, we see how Tom managed to not offload the instruction to the simulation by asking questions and probing for understanding.

> *Activity: Data Representation*
>
> Next, I will set the masses equal, choose a set of velocities for the two objects (velocities can be arbitrary, as they will remain constant during this part of the discussion). Again with the elasticity at 100%, we will see what happens during a collision. This time, I will phrase my question differently: "So what is the total change in energy of this system during this collision?" I expect that a student will quickly say that the change is zero, as the energy has remained constant.
>
> Now, I will decrease the elasticity to 80% and ask students, "Did anything look different this time?" Students will again likely point to the kinetic energy, as it is the most notable thing that changes. Additionally the final speed of each object is slightly different, but not to an incredibly noticeable degree yet. I will tell students: "Maybe we should write this final energy value down so we can use it later to compare energies."
>
> I will continue in this fashion, dropping the elasticity by 20% increments and having students collect data until we get to 0% elasticity. This case is an interesting one called a *perfectly inelastic collision*. During this type of interaction, the objects collide and then continue travelling (or not travelling) with the same velocity, which means they are "stuck together". I intend to bring students to this important point through questioning along the lines of: "Woah! So what happened here?" Students will likely say that the objects "stuck together" in

> this case, or that their velocities are the same. We will see that inelasticity has a limit beyond which it cannot be more inelastic.
>
> Students will then graph their findings and report on the results. There are several ways to graph this relationship. Students can either graph the percent change of kinetic energy, percent remaining of kinetic energy, or just graph the final kinetic energy vs. percent elasticity. Ultimately they should be able to see from their graphs that in an elastic collision, energy is conserved as well as momentum. In an inelastic collision, only momentum is conserved.

During the interview around using technology in Lesson Plan 3 Tom pointed out how he had gone about his planning by starting with his existing curricular materials and thought about how they might be improved with a simulation.

> "Well so, I, my learning goals were to describe the differences between, um elastic and inelastic collisions. What those mean and relate it back, what would be at this point be the recent unit on energy. Um, and so I sort of sat with my textbook for the class and decided what I wanted to do was essentially do what their text book would tell them, which is the ideal case. But show it to them visually instead of saying read this and just trust that the equations just work out. So, what I tried to focus on was really sticking to the section of their textbook that goes through this. But having it so that I could show it in real time. So it's a little easier to digest." (Interview 1)

The move of starting with the curriculum materials and looking for a technology resource that supports those and the learning goals of the content was something only noticed in Tom's Interview 1 responses. All of the other PSST talked about finding a simulation that they liked first and creating lessons and learning goals that fit that simulation.

Finally, Tom's responses to Simulation Scenario 1 suggest a strong pedagogical content knowledge and technological content knowledge. In fact, he scored no less than adequate on the SSR for these knowledge components on Simulation Scenario 1. In the following excerpt we see how Tom makes a specific connection between how the task (answering specific questions posed by the teacher) gives students the best opportunity to engage (discussing the visual outcomes of the simulation) with the content (kinetic and potential energy) given this instructional strategy (class-wide discussion).

> *I think I would use this simulation as a way to start a class-wide discussion. I would put it up on the projector and start the simulation. When the cart stops at a, I would ask a student to justify what they saw happen in both the animation, and the change in graphs. Then, I would proceed to part b of the simulation, and ask a different student to explain the situation, and so on. In this way, I could even use the faults described above as a way to gauge student understanding of the concept of conservation of energy. If the students could point out where the graph becomes inaccurate and how it is wrong, I would know that they have a level of understanding that goes beyond just what they've been told, and that they are extrapolating meaning to describe situations that they haven't explicitly been informed of. If no students catch on to these faults I would attempt to draw their attention to them through questioning. For example: "Look at what happens after part f. Is this consistent with conservation of energy?"* (Simulation Scenario 1)

Despite making these connections Tom still offloaded a significant portion of his instruction to the simulation as demonstrated by this part of his response from his assignment:

> *As mentioned above, this activity would take the form of a discussion. I would plan to be mostly hands-off in the discussion, only chiming in to redirect or to move the conversation forward ("okay good, now let's move forward to part a").* (Simulation Scenario 1)

Throughout Tom's responses to the Simulation Scenario 1 assignment, he struggled to address components of technology in relation to the content and pedagogy (technological pedagogical knowledge and technological pedagogical content knowledge), scoring only 5 out of 26 points on this part of the SSR and all of those coming on the question that focused on the task he would have the students engage with.

Looking across the pre-intervention assignments shows Tom's growing ability to think about pedagogy while at the same time struggling to address technological ideas associated with that pedagogy. In the pre intervention assignments Tom never makes a connection between how specific parts of the simulations (either from the one he selected to use in Lesson Plan 3 or the Simulation Scenario 1 assignment) would or should impact his pedagogical decisions. For example, in the simulation he selected for Lesson Plan 3, part of the graph can be difficult to read, especially when student are viewing the graph from a distance, as is likely in the activity structure that Tom talks about in his Lesson Plan. In an ideal case Tom would consider how this might impact his students' ability to think about the content or how he might need to support that constraint in his planning.

4.1.4.4 *Gwen*

Gwen completed her internship in a racially diverse and economically disadvantaged suburban district. She had access to a smartboard and a set of iPads in her classroom, along with access to a school-wide computer lab. Gwen's Pre-TPACK Self-Assessment scores were the lowest among all students with 9 positive responses, 11 neutral responses, and 19 negative responses. Most notably, Gwen's dimension scores for content knowledge and pedagogical content knowledge were 4.25 and 3.25 respectively. All of the rest of her scores indicated a negative description of her own knowledge (technological knowledge – 2.86, pedagogical knowledge – 2.29, technological content knowledge – 2.5, technological pedagogical knowledge – 2.6, and TPACK – 2.13).

Given the level of Gwen's self-reported TPACK scores, it was surprising that she scored well on the LPR in comparison to the other PSST on Lesson Plan 1, Lesson Plan 2, Instructional Performance 1, and Lesson Plan 3 (18, 22, 25, 33 respectively). In fact, Gwen had the best score on Lesson Plan 2 and second best on Instructional Performance 1.

Although Gwen showed continual growth in her ability to leverage planning practices across the pre-intervention assessments, Gwen, like all but one of her peers, offloaded her instruction to the technology resources for Lesson Plan 3. When asked about the focus of her planning during our interview, Gwen hinted that she might not have intended to offload the instruction to the simulation.

> "I think with my, during the group work, I kind of talked about how I would be walking around and what sort of things I would be looking for, um, but at the same time what questions I might ask if they are going off in the wrong direction, kind of bring them back to what I want them to get at." (Interview 1)

Although she talked about monitoring and asking questions during the interview, her lesson plan included only this description:

> *As I walk around I will use my monitoring tool to keep track of students' work and key features that they should be noticing. For most of my monitoring I will be taking notes…* (Lesson Plan 3)

This choice to offload the primary instructional work to the technology resources was also seen in Gwen's response to the Simulation Scenario 1 assignment task question:

> *…The teacher would discuss with the students how natural selection could cause a population to decrease causing certain allele frequencies to decrease, while increasing others. The students would discuss this concept with each other and their teacher, and following their discussion can use this simulation as a guide/reinforcement.* (Simulation Scenario 1)

In fact, despite the growth she showed in her early lesson plans, Gwen's SSR score for Simulation Scenario 1 was the lowest of all students (13 points), with only 2 scores of adequate across the 17 coded categories.

Looking across the pre intervention data, Gwen shows an early level of skepticism about her own knowledge and abilities. Despite this early uncertainty, she demonstrates signs of developing the ability to talk about planning practices that support facilitating discussions (monitoring students work) and a focus on engaging students with the content best represented by the technology.

4.1.4.5 *Janet*

Janet was the other PSST enrolled in the dual certification (science and special education) program. Her internship occurred in the same district as Alice; however, her placement was located at the middle school teaching physical and advanced physical science. Like Alice, Janet's classroom had its own dedicated laptop cart and teacher computer with projector.

Janet's Pre-TPACK Self-Assessment scores demonstrated a very high level of knowledge with 28 positive, 8 neutral, and 3 negative responses. Looking at the individual dimensions, her lowest score was 3.25 for technological content knowledge, still on the positive side of neutral. She also had three scores of 4 or larger (content knowledge- 4.0 , pedagogical knowledge- 4.1, technological pedagogical knowledge- 4.2). Janet showed a higher score on technological pedagogical knowledge (4.2) than pedagogical content knowledge (3.5) and technological content knowledge (3.25) despite having a greater score in content knowledge (4.0) and pedagogical knowledge (4.1) compared to technological knowledge (3.4).

Janet scored a 27 out of 71 (11 of 32 on the technology dimensions) on the LPR for her Lesson Plan 3 assignment. The plan showed strong evidence of supporting students as they worked, while at the same time not offloading instruction on the curricular resources. In her interview she discussed how hard she worked in her planning to think about how to connect the work the students would engage in with the learning goals she wanted them to get out of the lesson. Despite this focus on connecting student work with the learning goals, Janet was unable to make the connection of how the technology would actually support those goals and work. Her primary focus with the technology was making sure it functioned properly in the classroom rather than supporting students' thinking about the variables displayed in the simulation.

> "I kept thinking of ways to keep coming back to the learning goals to make sure that the students got them out of the lesson. So as I was planning again, maybe what the students were thinking. I wanted to connect it to their prior knowledge again with pressure and temperature and volume. So I wanted to have a quick review of variables so that we could really focus on understanding the relationship between two variables. I focused more on the technology working this time. Um, I had the technology, the computer out already. Normally they are in the computer cart. I wanted to have them ready so we were

> really focused on getting everything setup. We could just move on with the lesson. " (Interview 1)

Janet also explained in the interview that her selection of this particular simulation had very little to do with its ability to support the learning goals or instruction and much more to do with satisfying of her mentor teacher. Janet's mentor teacher had a desire to use resources already purchased by the district, regardless of their ability to support the content.

> "Well I picked the simulation based on, um, my mentor teacher suggested this simulation because they were signed up for this program and they paid money for this. So we wanted to use the simulations. So I did pick the simulation and then I made these learning goals." (Interview 1)

Finally, in her response to the task question on the Simulation Scenario 1 assignment Janet demonstrated a desire to engage her students with the science and engineering practices of developing and using models and analyzing and interpreting data. However, Janet made no specific connection between the task she wanted the students to engage with, how the technology (the given simulation) could actually support engaging the students in that work, or how any of those things might relate to analyzing or interpreting data.

> *If I were given this simulation, I would first introduce the content to my students. I would have them explore the simulation, write down the patterns they noticed, and draw a diagram of how the sun's rays look from around where we are on earth. I would also have them draw out what the orbit of earth around the sun looks like in the month I was presenting the material. That way, the students can explore the content but also have some context for their learning. I would ask them what they noticed and have them share their results. (Simulation Scenario 1)*

Although Janet had the second to lowest LPR score for Lesson Plan 3, she demonstrated a great deal of ability to think about planning practices in her Interview 1 responses. She talked about wanting to plan student engagement with the task and technology in ways that connect to the content (engagement with technology) (support materials). Yet she continued to offload instruction to the materials or technology in her planning and ultimately showed limited capacity in her planning around how technology could support engaged science learning.

4.1.4.6 *Jay*

Jay's internship site was a culturally diverse University-based laboratory middle school, in which he was teaching physical science. This placement included significant technological resources and supports including a classroom smartboard and teacher computer, access to a school computer lab, laptop cart, and Google accounts, mail, and tools. Along with these resources Jay's school subscribed to a Discovery Channel Video service and had access to a computer based homework hotline software.

On his Pre-TPACK Self-Assessment Jay answered positively on 31 statements, neutral on 8 and negatively on none of the 39 total statements. His lowest average knowledge score was pedagogical knowledge (3.57) and he averaged 4 or above on content knowledge, pedagogical content knowledge, technological content knowledge, and technological pedagogical content knowledge. Jay also scored 36 out of 57 on the SSR for Simulation Scenario 1, a full ten points higher than the next best PSST score on this scenario. He was also the only PSST to make explicit connections between the tasks he would engage the students with and the technology and learning goals on the Simulation Scenario 1 assignment.

> *I would have students calculate their own allele frequencies in addition to just using the ones generated by the simulation. I might have students take a screenshot of half of the simulation screen (to make counting more manageable), and then list how many of each color ant they see, and then relate the colors to genotype, and then calculate the allele frequency. That way they would have practice with learning goal 1. After running the simulation for two or three generations and seeing the effects of natural selection, I would have students predict if they thought one phenotype of ant was going to completely disappear, and why.* (Simulation Scenario 1)

Looking across this data suggests that he also had a strong interest and ability to think about technology in his planning from the beginning of the pedagogy course sequence. Jay demonstrated an early capacity to plan lessons aligned with the LPR and SSR rubrics. He also had an ability to talk about making connections between the planning he did, how he thought about the content, and how this pertained to the learning goals for each lesson as demonstrated in the following quote from Interview 1.

> "So we made, or I made a group spreadsheet for the whole class to compile their data in. And, um, I decided we could use that to explore some concepts related to data in general. I focused on outliers and the effects they have on averages. I wanted them to notice how having more data the effect of having one outlier would be diminished as opposed to if you have a smaller data set. I was unsure if that was enough for a whole lesson, since they aren't really doing any more data transformations than just the average I didn't want to add things in there, um, that weren't related to what they were doing." (Interview 1)

Finally, despite this ability to think in terms of learning goals and supporting students' thinking, Jay's planning still showed signs of offloading instruction to the curriculum and technology materials. In his response to the description of interactions question on his Simulation Scenario 1 Jay ends his response by suggesting that the students would be responsible for doing the work of counting the ants and taking screen captures while the teacher would primarily monitor them in a way that only responded to student requests for assistance.

> *…I would probably conduct this activity in pairs and select the pairs to try to pre-empt potential struggles such as difficulties with reading level, interacting with the computers, and the integration of math concepts into the lesson. It would also be helpful to help split up the slightly tedious work of counting the ants for gene frequency. Although it is a somewhat tedious task I think it is valuable because it give students direct practice with learning goal one rather than just seeing the results of given frequencies, and having a partner should reduce the challenges that are not cognitively demanding. Their interaction with the teacher would be to ask for assistance or clarification…* (Simulation Scenario 1)

This was not just exhibited by on the Simulation Scenario 1 but by his description of the demand of his Lesson Plan 3 in our first interview:

> “But mostly I just thought and made up a worksheet they could do thinking through those sorts of things. They could change in that data and look for… But I feel like it's the task I am thinking about, focusing on the most. Anything else sort of falls out naturally from the task." (Interview 1)

Regardless of his LPR score, which was very low, Jay demonstrated a great deal of thinking about and use of planning practices in his Interview 1 data. In fact, he showed a great deal of ability to make connections between the technology, content and pedagogy in service of a task that engages students. Although he did communicate these practices in the interview, very few, if any, made their way into his Lesson Plan 3. Given his TPACK scores and ability to talk about these planning practices, his inability to leverage this in his planning was a little surprising, but likely more of a byproduct of learning the skill of writing lesson plans than an indication of inability to leverage these planning practices as he designed lessons.

4.1.5 Summation

Looking across the data associated with research question one, including the interview data and the cases presented, we see that, prior to the technology intervention, the PSST were not inclined to plan lessons that leveraged technology in support of engaged science learning. I speculate that this was likely the result of attending to other planning practices associated with planning dimensions (launch and task) that were stressed in the early portion of the pedagogy course sequence. In fact, a limitation of the data associated with research question one was that the number of opportunities for the PSST to engage in planning prior to the simulation intervention, combined with the structured nature of those opportunities (they were all pedagogy course assignments), limited the scope of the lesson data collected. The structured nature of the assignments, focusing PSST work on planning practices associated with the 5 Practices and demanding tasks, likely precluded the students from attempting to integrate technology into the lessons. Despite this limitation, this sequence of pedagogy course lessons and assignments was critical to the development of the PSST ability to plan and think about engaging science instruction.

The PSST, even when required to use technology in their Lesson Plan Assignment 3, showed little ability to connect the technology and its resources to the pedagogy or content in their written plans. However, as demonstrated in the PSST cases (4.1.4), which included data from Interview 1, we see some clearer connections in the way the PSST are talking about their planning practices around technology than the way they wrote about them in their Lesson Plan 3 or Simulation Scenario 1. This disconnect between the written lesson plans and the PSST interview data is not surprising as others have shown that lesson plans do not always capture all of the thinking done by teachers during their planning (Ross, 2014; Hughes, 2006; Shoenfeld, 1998).

Overall the PSST demonstrated a great deal of development across these pedagogy course assignments. They begin with almost no ability or desire to think about the use of technology in their planning. By the end of this portion of the pedagogy sequence, the PSST are beginning to demonstrate the ability to talk about planning practices associated with using technology (supporting student engagement with the technology, connecting content and affordances of technology, and managing student work with the technology). Although many of these practices only appeared in the interview data, as we see in the next section this ability to talk about planning practices shifts into the PSST actual planning documents.

4.2 RESEARCH QUESTION 2: WHAT DO PSST ATTEND TO AROUND THE USE OF COMPUTER SIMULATIONS IN THEIR PLANNING AFTER PROGRAM INTERVENTION?

Following the pedagogy course sequence on the *5 Practices for Facilitating Task-Based Discussion*, the PSST participated in a set of lessons designed to help them think about, understand, and plan engaging science lessons supported with computer simulations. Upon completion of these lessons, PSST completed two assignments: Instructional Performance 2 and Simulation Scenario 2. The data reported in this section includes LPR scores from Instructional Performance 2, excerpts from individual PSST Instructional Performance 2 assignment, Interview 2 data (centered on Instructional Performance 2), SSR results from Simulation Scenario 2, and excerpts from the Simulation Scenario 2 assignment responses.

4.2.1 Simulation Based Assignments Post Simulation Intervention

4.2.1.1 *Instructional Performance 2*

Using the same LPR codes as from the Lesson Plan 3 analysis, Figure 11 shows the PSST codes on the seven lesson plan dimensions for Instructional Performance 2. The LPR scores on Instructional Performance 2 were the highest recorded on any lesson plan for all PSST, with the exception of Courtney. These high overall scores are also reflected in the technology dimensions of the rubric with 4 of the 6 PSST recording their highest technology scores on this assignment.

			Courtney	Jay	Gwen	Janet	Alice	Tom
IP 2	Launch	Connection to previous work	1	3	2	2	3	1
		Motivates student participation	0	2	3	1	3	2
		Communicates the purpose of task	0	2	3	3	3	2
		Communicates the expectations of the task	1	1	2	3	2	2
		Communicates instructions on using the technology	0	2	3	3	2	1
	Tasks	Initial Level of CD	1	1	1	1	1	1
		SEP use	1	1	1	0	1	1
		Offloading work to curriculum materials	0	0	1	1	0	1
	SP/General Worktime	Supporting Task: Anticipating	1	1	3	2	2	2
		Supporting Task: Questions	1	1	2	1	2	1
		Supporting Tasks: Materials	2	3	2	2	3	2
		Supporting Task: LG Conection	0	2	3	0	2	2
		Support of task demand across work time	0	1	1	0	0	0
	Technology Worktime	Engagement with Technology	1	2	3	1	2	2
		Management of student work with technology	2	2	3	2	2	2
		Maintaining Demand	0	0	2	0	1	0
		Offloading work to technology	0	0	1	0	0	1
	Technology Resource	Description of Affordances	0	3	0	0	3	1
		Description of Constraints	0	2	1	0	2	2
	TPACK	PCK	0	2	3	1	2	3
		TCK	0	3	3	1	2	1
		TPK	0	1	3	1	1	1
		TPACK	0	1	3	0	1	1
	Close	Connects to main ideas of lesson	0	2	3	1	2	2
		Connections to future work	0	1	2	1	2	2
		Communicates requirements (HW, assignments, next steps)	2	1	2	0	0	2
		Total	13	40	56	27	44	38

Figure 11. PSST Instructional Performance 2 LPR Codes and Total Scores

Examining the individual dimensions of the LPR for Instructional Performance 2, 5 of 6 PSST were assigned positive scores ("Very Strong" or "Adequate") across the launch. This included the PSST planning to communicate the purpose and instructions associated with students using the simulations. In regards to the task dimension, PSST were continuing to use Science and Engineering Practices, however, they were still struggling with planning high demand tasks. On Instructional Performance 2 Tom was the only PSST who planned a high demand task for his students to engage in as they used a simulation. Tom and Gwen were the only two students to not offload instructional work to either the curriculum materials or the simulation.

With respect to the technology dimensions of the LPR, the PSST attended to how they would manage students interactions with the simulation in their planning, as each PSST scored adequate or above on this practice. Most of the PSST (4 out of 6) also attended to how they would get students to engage with the simulations in their planning. The PSST still struggled with offloading instructional responsibilities onto the simulations, while demonstrating mixed levels of planning in regards to describing affordances and constraints of the simulations and how these were addressed or leveraged during planning or instruction.

Finally, it is important to point out Courtney's LPR score, as it is an outlier in this data. As talked about throughout other parts of this chapter, Courtney found the issues at her internship regarding gaining access to technology to be untenable. Despite numerous attempts to gain access to resources, she was denied the ability to use the computer lab or computer carts. This limited access had an impact on her planning as seen in her LPR for Instructional Performance 2 and in other data reported throughout the rest of this chapter.

In summary, these LPR results for Instructional Performance 2 suggest that while most PSST ability to leverage planning practices around the technology dimensions was still in development (in the sense of their written work), they were not abandoning the work associated with the planning practices of the task dimension of the lesson plan. This could be the result of strong interconnectedness between the dimensions or it could be the result of the PSST adherence to a set of practices in their planning that was a major focus early in the pedagogy course work. At this point in their preparation program (immediately following the technology intervention), all of the PSST attended to the practices of developing supportive materials in service of the task and managing students' work with the technology. However, PSST demonstrated mixed results for all of the other technology dimensions measured on the LPR except maintaining demand, for which only one student (Gwen) scored adequate. This points to the PSST developing the ability to think about and support tasks and initial engagement (focusing on students actually using the materials), while not supporting them in the work of sustained engagement over the course of the lesson. The absence of a clear pattern across the different planning practices indicates the process of taking up and integrating these complex planning practices is highly individualized.

4.2.1.2 *Simulation Scenario 2*

Simulation Scenario 2 was assigned to the PSST at the end of the pedagogy course class that followed the completion of the simulation technology intervention. Like Simulation Scenario 1, the PSST were given 48 hours to respond to the assignment and email their responses to the course instructor. Simulation Scenario 2 did not actually count as part of the pedagogy course grade and the PSST did not receive any feedback on this scenario. Using the same Simulation Scenario Rubric (SSR) discussed in section 4.1.3.2 of this chapter, the PSST responses to the Simulation Scenario 2 assignment were coded and the results are reported in Table 15.

Table 15. PSST SSR scores for Simulation Scenario 2

		Courtney	Jay	Gwen	Janet	Alice	Tom
Affordances	PCK	3	4	4	4	2	4
	TCK	3	4	3	4	3	4
	TPK	2	1	1	2	1	4
	TPACK	0	1	1	2	1	4
Constraints	PCK	2	3	4	2	2	4
	TCK	3	4	4	2	3	4
	TPK	2	2	2	3	1	4
	TPACK	1	2	2	2	1	4
Tasks	PCK	2	2	4	2	3	4
	TCK	2	1	4	1	2	4
	TPK	2	0	3	1	3	4
	TPACK	1	0	3	1	3	4
Description of Resources		3	2	3	3	1	4
Description of Interactions (Dichotomous)	PCK	0	1	1	1	1	1
	TCK	0	1	1	1	1	1
	TPK	1	1	1	0	0	0
	TPACK	1	1	1	0	0	0
Offload (Dichotomous)		0	1	0	0	0	0
Total		28	31	42	31	28	54

Similar to the results seen on Instructional Performance 2 scores, PSST earned their highest SSR scores on the Simulation Scenario 2 assignment. The data suggest that the PSST demonstrated various levels of knowledge and planning practices. Despite this distribution, the PSST, on a whole, did very well in the areas of pedagogical content knowledge (no score below some knowledge) and technological content knowledge (20 of 24 individual scores above some knowledge). The PSST also did much better on areas related to thinking about affordances than constraints or tasks. Also of note, the PSST demonstrated a high level of description of the resources (Question 4) they would use to engage students with the simulation. Finally, 5 of the 6 PSST continued to offload instruction to the resources or technology instead of supporting instruction through interactions with the students.

Comparing the Instructional Performance 2 and Simulation Scenario 2 trends show that the PSST demonstrated mostly mixed results across many of the planning dimensions. It is clear that the PSST were attending to many more of the technology dimensions of the LPR (compared to early work in the pedagogy course). Specifically, the PSST were able to select simulations that supported the task in productive ways. They were also able to plan purposeful ways to introduce the simulation to students during instruction. However, they were unable to attend to the work of planning ways to support students' leveraging those simulations for the purpose of building conceptual knowledge during instruction. In other words, the PSST failed to plan to support the student thinking, noticing, or work around the content. Rather, they expected the materials or technology to accomplish most of this work for them.

Also of note, the PSST thought about and engaged with the less authentic Simulation Scenario 2 more than they did on the more authentic Instructional Performance 2. In fact, overall the PSST scored much better on the Simulation Scenario 2 in proportion then they did on Instructional Performance 2. As an example, Janet attended to very few of the technology dimensions on her Instructional Performance 2. In the excerpt from her Instructional Performance 2 (Figure 12) we see the only portion of her instructional performance assignment where she writes about students' use of the simulation that she has selected and how it will be supported. A key feature of this portion of her instructional performance is that she included only minimal connections to the content being covered (Bohr model) or how to support content ideas (directing student to the mass number tab). Instead Janet focused much of her attention on expectations for the task and behavior or task enactment issues.

- We are going to be using this simulation to create a Bohr model of specific elements. You will need your periodic table. **Each group is going to be making three element's Bohr models. Underneath your group name will be the three elements you will make on the simulation, and then draw it exactly how it looks on your screen in your handout.**
- I will give you some time to explore the simulation. However when you are doing this you are to complete pages 2-5 in your handout.
- **You will have 20 minutes to complete the activity and complete the questions. At 10:00 we will come back together as a group to discuss your answers to page 5 of your handout.**
- I will monitor the room with my monitoring chart for each group.
- At 10:00 I will collect each member's handout and go through the questions on page 5. I will ask for a presenter from each group to talk about the patterns that they noticed. (5 minutes)

- Anticipated Responses:
  -Off task behavior, I will address off task behavior as it arises by monitoring the room and having the assistance of the inclusion teacher and sub. I will have what the students are supposed to be doing posted on the powerpoint, so I can have them refer back to what they are doing
  -Not understanding task, I can assist students in making their first element's Bohr model if groups are still confused. I made groups so that a stronger student will be in each group.
  -I will point out the mass number tab if students are confused about what neutrons do in an atom.
  -Groups not talking, we had a lengthy discussion about working with others but I can remind students that it is sometimes necessary to work with people who are not our best friends.

Figure 12. Portion of Janet's Instructional Performance Related to Simulation.

This is in sharp contrast to her Simulation Scenario 2. When asked to write about the affordances of the simulation, Janet was able to describe in detail (Figure 13) the connection to the content covered and how the simulation could be integrated by the students in support of that content.

1. Affordances of this simulation include the physical representation of the abstract particles. This helps students be able to conceptualize Kinetic Molecular Theory principles. The students' have the ability to interact with the simulation and manipulate the particles in different ways. Students will save time interacting with this simulation rather than performing an experiment. Students will also be able to describe what temperature water freezes, melts, and vaporizes because of the thermometer. Students will also be able to determine that different substances freeze/melt/vaporize at different temperatures. This lends toward the idea that different substances have different identifying properties.

   The simulation will help students achieve LG 1 because they can manipulate the addition/removal of heat and observe how the motion of particles change. The simulation will also help students achieve LG 2 because students can observe how particles in different states interact with each other.

Figure 13. Janet's Simulation Scenario Assignment 2 Question 1 Response.

This result is telling in that it highlights the complexity of the work associated with Instructional Performance 2. The less authentic work of the Simulation Scenario 2 allowed PSST to focus solely on thinking about the simulation and how it connected to the content and instruction they wanted to design. In the Simulation Scenario 2, that content (the learning goals) was already specified and little effort was required to think about the work of making the planned instruction connect across multiple lessons or students (very few PSST attended to this part of the scenario). The mostly positive results across the PSST on the SSR revealed an ability to think and leverage their knowledge of technology, pedagogy and content when the work of selecting the content and resource was already completed for them.

This result is in contrast to the complexity of Instructional Performance 2. In this work the PSST had to consider all of the dimensions of planning and needed to do so in a way that was responsive to all of the complex contextual features of their internship (students' attitudes and dispositions, their mentors' wishes, curriculum, access to resources, etc.). This complexity seemed to draw PSST attention away from using planning practices associated with the technology dimensions of the lesson plan and focus their attention on specific planning routines.

Also, as mentioned in the discussion of research question one earlier in this chapter, although the PSST seemed to have mixed results in regard to the planning practices they wrote about in their lesson plan for Instructional Performance 2, they all seemed to be able to talk in much greater detail about their planning during the interview around Instructional Performance 2.

Finally, the Simulation Scenario 1 data demonstrate that the PSST really started thinking about how the affordances of the technology were going to have an impact on the pedagogical and content related areas of their instruction and lesson design. They also wrote about how their task choices would be shaped by the specific learning goals provided in the scenario. This explicit and specific connection to learning goals as a driver of planning is part of a set of planning routines that emerged from the data and that are explained in the next section.

4.2.2 Planning Routines

Looking across the Instructional Performance 2, Simulation Scenario 2, and Interview 2 data, an emergent pattern of PSST consistently using the same sets of practices in combination came to light. These *planning routines* (Attending to Learning Goals, Attending to Task Selection and Design, Attending to Supporting Materials, and Attending to Features of the Technology), which are made up of individual planning practices, seemed to be a central focus of the PSST work in planning with the simulations to support engaged science learning. Although these assignments did require the PSST to plan with and use a simulation, they did not stipulate how the PSST went about the work of planning. The fact that such a clear set of planning routines emerged from the data suggest a strong link to the PSST taking up the practices presented in the pedagogy course sequence in similar and interesting ways.

4.2.2.1 *Attending to Learning Goals*

Looking across the Instructional Performance 2 assignment and interview data, the PSST showed a pattern of starting the planning process with learning goals as compared to starting with selecting a technology and adding learning goals to it. This move, of starting the planning process with learning goals and selecting simulations that would ultimately support those goals, was taken up in slightly different ways by each of the PSST. Yet, all the PSST had a consistent theme that involved using the learning goals in focusing their planning efforts. In fact, all six of the PSST demonstrated this planning routine regardless of their overall success in planning with the simulation. The following quote from the interview with Janet demonstrates the central idea of this routine:

> "The technology was me going to, off the learning goals and trying to find something that would fit into this unit." (Interview 2)

Likewise, in Interview 2 Alice discussed her desire to have her students think about the ideas of stoichiometry before getting into the heavy math calculations usually associated with that unit of chemistry. She started with these goals and said that she "decided to find a simulation that fit these learning goals". From the various PSST responses during Interview 2, it is clear that the routine of anchoring planning choices by starting with learning goals for their students was well adopted. Along with the PSST talking extensively about this routine in their interview data, we see examples of the PSST making specific links to their lesson learning goals in their written lesson plans, especially in the launch portions of their plans. In figure 14 Alice makes a specific connection to her learning goal in the launch portion of her plan. This connection included a link to how she would actually address this with her students when she was presenting the "Today's Class" slide.

Learning Goals The relative ratios of reactants in a chemical reaction allow for prediction of the amount of products formed from a chemical reaction.

Launch

There will be a slide (see below) projected to correspond with the following explanation of today's task, "Now that we have explored the classes of reactions as well as writing these reactions completely and correctly, we are going to start working on answering the question we just discussed in our warm-up: How do we determine amounts of products formed in reactions?...

We need very specific ratios of the substances in a chemical reaction to form the intended products of the reaction. What numbers in the reaction help us determine these ratios?"...

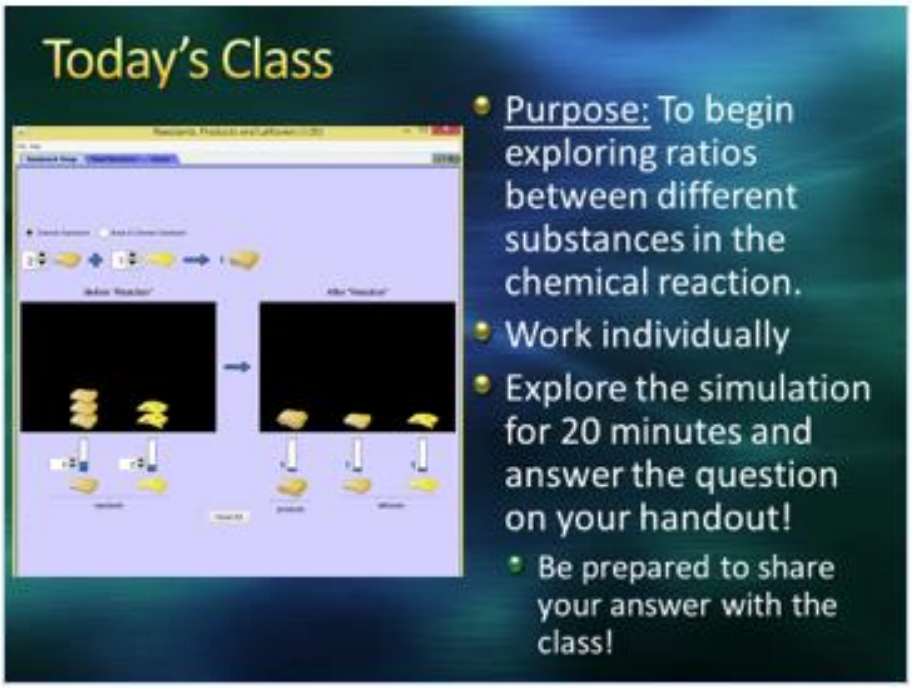


Figure 14. Composed Excerpt From Alice's Instructional Performance 2

When asked in his interview what he focused on when he was doing his planning for this lesson, Jay responded:

> "I focused on the learning goals first and how I would use the simulation to get them to make those connections about waters structure and chemical behavior and I also tried to anticipate how they would use the simulation and make a work sheet to scaffold their progress through it." (Interview 2)

Again, this focus on using the learning goals as the starting point in planning instruction was not just something he talked about in his interview but was present throughout his lesson plan. In Figure 15 Jay makes an explicit connection to his stated learning goals in his sections labeled "Student Simulation Engagement" and "Launch".

Learning Goals:

- Electronegativity is a measure of how strongly atoms attract electrons.
- Different elements have different, set electronegativities.
- Water is a polar molecule because it has a partial positive and partial negative end.
- Water's polarity allows it to act as a solvent for other charged species.

Student Simulation Engagement:

I chose this simulation because it offered several affordances and few constraints from my perspective. I found that it was easy to use without including too much extraneous information, highlighted the concepts I wanted students to learn about water's polarity, and included a water molecule in the third tab with real electronegativity values.

Launch:

I will tell the students that this activity should help them understand how water's physical properties are related to some of its unique characteristics, which they have already researched for the background sections of their water papers, and that this information should help them when they revise their papers and write their final drafts.

Figure 15. Composed Excerpt From Jay's Instructional Performance 2

4.2.2.2 *Attending to Task Selection and Design*

All of the PSST engaged in the planning routine of selecting and designing the tasks their students would be engaging in during the lesson. Although all but one PSST, Tom, ultimately planned low demand tasks, they all demonstrated a focus on thinking about designing tasks that got students to engage with the simulation in ways that related back to the content. In these lesson plans that content was most often associated with the learning goals. In other words, the PSST did not just select simulations that supported the learning goals and then simply let the students work on the simulations. The PSST instead crafted tasks that encouraged their students to engage with the simulations in meaningful ways to support student development of the learning goals.

In Interview 2 Gwen talked about how she had attended to creating a task that focused students' attention on the learning goals while allowing students to engage with one another. She did this by having the students work in small groups going from station to station observing different phenomena of water, including using a simulation focused on water molecules interacting with one another. In her Instructional Performance 2 lesson plan she wrote:

> *I will then tell the students that we are going to begin our lab in a few minutes but first we are going to go over exactly what you will be doing. At each station you will be testing and observing different properties of water. At each station you will complete the task in order to answer various questions and complete the chart in your worksheet. Each group will work together in order to make their observations and record them in the worksheet.* (Instructional Performance 2)

Although the way the task was designed did not make it high demand, Gwen had a clear focus on planning the task. This focus on tasks in planning was something seen in PSST interview after PSST interview. As another example from Interview 2, Alice said:

> "I was really focused on the task and how I wanted the students to interact with this particularly because it was the beginning of the unit. So I didn't want them to do a lot of calculations with it. I wanted them to just explore the different, I don't know what to call them, the different tabs they could explore in the simulation. So they could see a more practical example." (Interview 2)

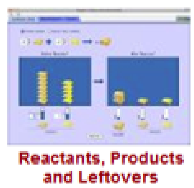
Along with thinking about and planning these tasks, the PSST also attended to providing opportunities for students to engage in the NGSS science and engineering practices. In fact all of the PSST planned tasks that engaged their students in at least one of the SEP for Instructional Performance 2.

4.2.2.3 *Attending to Support Materials*

Five of the six PSST engaged in a planning routine focused on developing or adapting their own set of materials, specific to their context and setting, for students to use while they engaged with their selected simulations in Instructional Performance 2. These materials ranged from full handouts (Figure 16) to simple guiding questions for class discussions (Figure 17).

Name:____

Reactants, Products, and Leftovers Simulation



First: Go to http://phet.colorado.edu.

Click through the following sequence:

Play with the Sims → *Chemistry* → *Reactants, Products, and Leftovers* → Run Now!

If a yellow bar drops down in your browser, click on it and select "Allow Blocked Content"

Part 1: Making Sandwiches: Sandwich Shop

Take some time and familiarize yourself with the simulation. Explore the different options and change different values.

Part 2: Real Chemical Reactions: Real Reaction

Now let's work with real chemical reaction, one that creates a very entertaining BOOM! Take some time and familiarize yourself with the simulation. Explore the different options and change different values.

Use the simulation to answer the following question, providing examples from the simulation in your answer:

What is a limiting reactant and how is it related to the overall chemical reaction?

Figure 16. Alice's Handout 1 From Instructional Performance 2

What patterns did you notice with excess protons and electrons? (protons +, electrons -_

What was the word the kept replacing "Neutral" when you added a proton or electron? Ion (atom that has an unbalanced charge)

Can we make any improvements to our diagram from the beginning of class?

Did anyone notice anything about the effect of Neutrons? (Mass #)

Figure 17. Guiding Questions for Discussion From Janet's Instructional Performance

In Tom's interview he talked about the reason he selected his simulation. He noted that, aside from being well connected to his learning goals, he chose the simulation because he felt that the resources associated with it could be adapted for his particular students.

> "I chose (the simulation) because I knew it would do what I want it to do and it had several lesson plans and activities on the PhET website that other teachers have uploaded. I went and looked at it and I really liked the format and what it was trying to do. And I think it aligned pretty well with my learning goals and so I went through and played with the simulation and looked through those questions and altered them as I was kind of learning more about the simulation and altered them to fit my class." (Interview 2)

In his interview, Jay made a similar connection. He actually took it one step further, mentioning that he really tried to make a worksheet (Fig. 18) that scaffolded students' ability to see the things he wanted them to in the simulation.

> "I focused on the learning goals first and how I would use the simulation to get them to make those connections about water's structure and chemical behavior and I also tried to anticipate how they would use the simulation and make a worksheet to scaffold their progress through it." (Interview 2)

Figure 18 shows a portion of the worksheet that Tom created to scaffold his students' work on projectile motion. You can see how the questions that Tom asked the students to consider really focused their attention on important features of the simulation that helped connect to the learning goals.

In your lab report, include a neat data table and graph of your results with all proper conventions (title, labeled axes, units, and so on). Answer all of the following questions in complete sentences:

1. Explain how your group's procedure made sure each ball started with the same velocity. Did this work out as you planned it? If not, what modifications did you have to make to your procedure

2. Do you see a correlation between the mass of the ball and the distance it travelled? What pattern or patterns do you see? Why is this?

3. Momentum is a term that means the product of its mass and velocity. Momentum (p) = m*v. Calculate the average momentum for each ball you tested, showing your work. Do not forget to include units.

4. How is an object's momentum related to how far it will travel before stopping?

5. If we wanted give two balls with identical masses different momentums, what would we need to change?

6. Discuss at least three sources of error in your experiment, and what you would do differently if you could do it again.

Figure 18. Portion of Tom's Instructional Performance 2 Worksheet

4.2.2.4 *Attending to Features of the Technology*

The final planning routine that all of the PSST attended to was the features of the simulations they selected. This planning routine required PSST to attend to the either the planning practice describing the affordances or the constraints. Using this description they could then engage in other practices, like anticipating students work on the task.

Only 3 of the PSST attended to the affordances of the simulations in their Instructional Performance 2 lesson plans. On the other hand, 4 of PSST attended to the constraints of the simulations in Instructional Performance 2. Even when PSST did not explicitly address affordances in their written lesson plans, they all talked about attending to this feature during Interview 2. Specifically, they described how the technology provided opportunities for students to engage with phenomena and/or learn specific ideas. Five of the six PSST responses revolved around supporting students being able to gain visual exposure to the content phenomena. For example, Tom stated that part of his decision to use the PhET simulation on projectile motion was:

> "because it is nice easy to use visual representations. The way the variables were represented was easy to see and allowed for a limiting of constraints of directing students where to go. It seemed like something they could use without much direction. Visual was important. Nice to show the situation in a representative visual way. Not just a graph but what the graph looks like." (Interview 2)

While supporting students' ability to see visual representations was an important factor given in many of the interviews, 5 of the PSST also talked about minimizing distractions in the simulation while highlighting things related to their specific learning goals. As an example, when Jay was talking about his simulation to get students to notice how atoms interact with different electronegativities he said:

> "I think it was pretty straightforward and easy to understand how to use it. Um, there weren't too many extraneous options. There were options you could toggle on and off that they might not have strictly needed but they didn't hurt either. Like the, um bond dipole arrows and they could see the values of electronegativities" (Interview 2)

4.2.2.5 *Summary*

The emergence of planning routines associated with how PSST carry out the work of designing instruction that leverages technology came to light in PSST responses from interview 2. Almost all PSST in this study leveraged four distinct planning routines (Attending to Learning Goals; Attending to the Selection and Design of Tasks; Attending to Support Materials; Attending to Features of Technology). Although each of the PSST engaged in a number of different planning practices associated with each planning routine, as discussed above and further in section 5.2, the routines were the primary focus of their planning. This is best exemplified in the example from section 4.2.1.3 (Attending to Supporting Materials). Alice's support materials (handout) focused on the planning practices of communicating the instructions for using the technology and management of student work with the technology. In comparison, Jay had created a set of support materials (questions on a handout) that focused on the practices of students engaging with the technology. Although they are both working within the same routine (attending to supporting materials) they were doing so in slightly different, yet equally meaningful ways. This slight difference in the way that the PSST leveraged planning practices in their routines suggest that the PSST were being attentive to the various factors associated with each individual internship, knowledge, and content factors.

4.2.3 Research Question 2A: In What Ways Do The Dimensions of Planning That PSST Learned Earlier In The Program Relate To The Ways They Plan With Computer Simulations?

In this section I report out the patterns of aggregate data from PSST Instructional Performance 2. The goal of asking this question was to identify if a pattern or relationship existed between the parts of planning for high demand task-based discussion (previously identified as being important) and parts of planning for technology. Table 16 shows the average scores for the various dimensions of the LPR for each student. Green values represent the dimensions PSST had an average score representing an adequate value on 2/3 of the dimension individual practices scores. Red values represent a score of less than adequate on 2/3 of the dimension individual practices scores.

The data suggest that no pattern emerged between the non-technology dimensions and the technology dimensions. For instance, Gwen scores well on the launch (2.6) and on technology worktime (2.3). Janet on the other hand scores well on launch (2.4), however, she scores poorly on technology worktime (0.8). Tom's launch score (1.6) is not very good, yet his technology worktime score (1.3) is pretty good. These confounding relationships are seen throughout the data and suggest no real patter to report.

Two possible exceptions do potentially exist. No PSST who scored well on the technology resources dimension did poorly on the launch dimension. Likewise, no student who scored well on the 5P worktime dimension did poorly on the launch dimension. As such, I cannot be certain that scoring well on the launch dimension is not a prerequisite for scoring well on either the technology resources or 5P worktime dimension.

Table 16. Averaged Dimension LPR Scores for Each PSST on Instructional Performance 2

	Courtney	Jay	Gwen	Janet	Alice	Tom
Launch	0.4	2.0	2.6	2.4	2.6	1.6
Task	0.7	0.7	1.0	0.7	0.7	1.0
5P Worktime	0.8	1.6	2.2	1.0	1.8	1.4
Technology Work time	0.8	1.0	2.3	0.8	1.3	1.3
Technology Resources	0.0	2.5	0.5	0.0	2.5	1.5
TPACK	0.0	1.8	3.0	0.8	1.5	1.5
Close	0.7	1.3	2.3	0.7	1.3	2.0

4.3 RESEARCH QUESTION 3: HOW DO CONTEXTUAL FACTORS IMPACT THE WAY IN WHICH PSST PLAN FOR LESSONS INVOLVING COMPUTER SIMULATIONS?

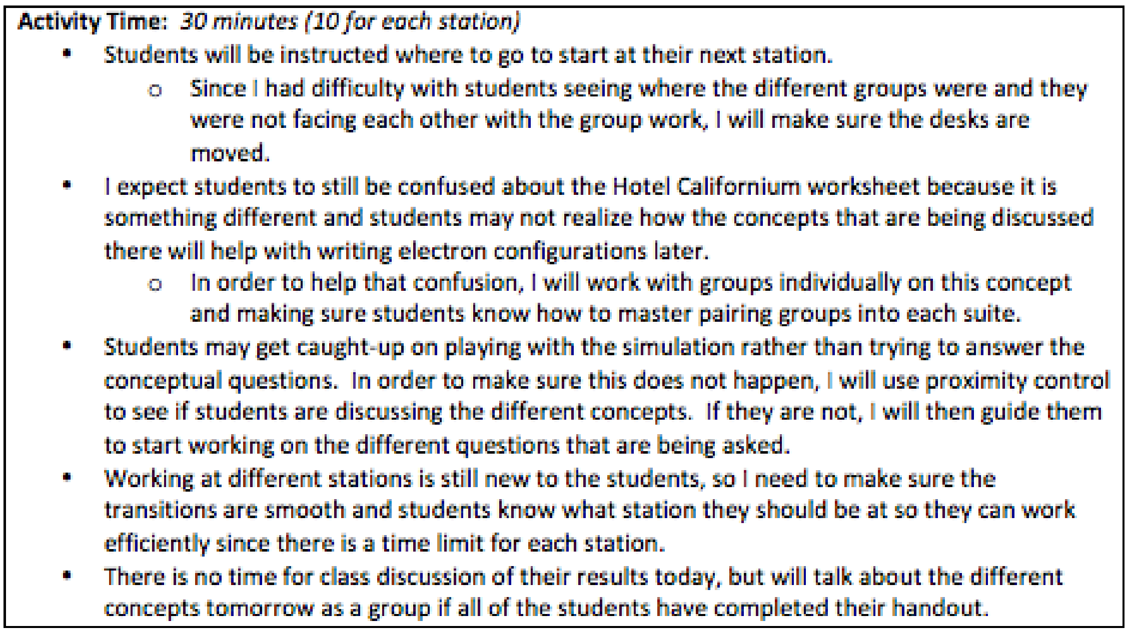
Context, more specifically the contextual features that PSST encounter at their placement site, was a factor in the way that they went about planning using simulations. In the examples below I show how contexts impacted PSST planning in very different ways.

4.3.1 Contextual Challenges

In her Instructional Performance 2 Interview Courtney talked extensively about the challenges she faced in gaining access to technology at her internship placement site. In the quote below from Interview 2, Courtney voices her frustration with not being able to get the computer lab so that her students could use a PhET simulation about the structure of the atom. She elaborates on how as a result she had to use a station activity in order to get her students to be engaged with the simulation.

> "Initially I was told at the beginning of the week that I wasn't going to be a problem. I'm going to be able to get the computer lab. That was false. There is someone who has signed it out, like everyday during the time period I need for a class, or at least three days a week. But, and those are the days we figured with this, and also with getting my supervisor to come and then the other days, pretty much until the end of the year are kind of booked. Just because we didn't get the computer link for a while, for some reason and we aren't able to check out, to go into the library, there is no laptops, there might be wifi but still there is no laptop cart so it doesn't really matter. So while there is, the good thing is, in the classroom we do have a smartboard. So that is something to utilize with technology that we wanted to use, but, I know with my students. With having a large class, so my classes have 33 students, that having only one person manipulating and answering questions, it didn't seem, like, students were going to be very disengaged. So that is why stations were created to have a smaller group so they can focus on the simulation." (Interview 2)

Notice in this quote she talks about stations as an option to keep students engaged, yet, she never makes any connections to what they should be engaged with or why. Her overall frustration with not being able to have students engage in the computer lab appeared to push her into a more classroom management focused planning approach as seen in the Activity Time portion of her Instructional Performance 2 lesson plan (Figure 19).



Activity Time: *30 minutes (10 for each station)*

- Students will be instructed where to go to start at their next station.
  - Since I had difficulty with students seeing where the different groups were and they were not facing each other with the group work, I will make sure the desks are moved.
- I expect students to still be confused about the Hotel Californium worksheet because it is something different and students may not realize how the concepts that are being discussed there will help with writing electron configurations later.
  - In order to help that confusion, I will work with groups individually on this concept and making sure students know how to master pairing groups into each suite.
- Students may get caught-up on playing with the simulation rather than trying to answer the conceptual questions. In order to make sure this does not happen, I will use proximity control to see if students are discussing the different concepts. If they are not, I will then guide them to start working on the different questions that are being asked.
- Working at different stations is still new to the students, so I need to make sure the transitions are smooth and students know what station they should be at so they can work efficiently since there is a time limit for each station.
- There is no time for class discussion of their results today, but will talk about the different concepts tomorrow as a group if all of the students have completed their handout.

Figure 19. Courtney's Activity Time Portion of Her Lesson Plan For Instructional Performance 2

Although this part of the lesson plan refers to supporting the Hotel Californium worksheet, this worksheet was not related to the simulation or the content covered in the simulation around atomic structure. In the final part of the lesson plan she suggest she will "guide them to start working on the different questions that are being asked", but she does so in a way that is more consistent with directing students to do work than getting them focused on the content. A majority of her references to the content in both Instructional Performance 2 and Interview 2 are centered on the work associated with stations not connected to the simulation or the stated learning goals associated with the simulation (Figure 20).

Learning Goals:

- Protons and neutrons can be found inside the nucleus of an atom, while the orbitals are found on the outside in orbital of the Bohr model.
- Ions are an atom or molecule with a net electric charge due to the loss or gain of one or more electrons.
- Electron configurations have rules, such as the Aufbau Principle, Pauli Exclusion Principle, and Hund's rule.
- When you move across a period, the atomic radius decreases while the atomic radius increases as you go down a column in the periodic table.

Figure 20. Courtney's Learning Goals From Instructional Performance 2

Like Courtney, Tom's internship setting was not ideal for getting students to engage with simulations. In Interview 2 Tom described how he had to schedule time in a computer lab as "it was the only option…of running a simulation" and how all of the work and time associated with getting himself and his students ready to engage with a simulation in a new setting was difficult. Despite these challenges, Tom still focused a large part of his lesson plan on supporting students' thinking about the content and learning goals. In the following excerpt from Tom's lesson plan from Instructional Performance 2 he makes explicit the content he hopes the students will take away from the lesson and why.

> *With this result, we can revisit the situation here and show that an object under two dimensional projectile motion behaves in each direction (x and y) as it would if it were under one dimensional kinematic motion in either of those directions. This result is vastly important, as we're going to be looking at two dimensional motion for the next two or so weeks, and this is an important detail to being able to solve practice problems.* (Instructional Performance 2)

The general context of these two examples looks very similar. However, in unpacking the nuances of these placement contexts (actual availability of resources, cooperating teachers' understanding and support) we see a different picture. Courtney's students were enrolled in a lower level (mainstream) science course and she worked with a mentor teacher who had only been teaching in the district for three years. By Courtney's own account, much of the planning work her and her mentor did was focused offloading (Forbes & Davis, 2010) of instruction to the curricular materials. In other words, her planning was focused on using a set of curriculum materials; usually her mentor teacher’s plan and support documents, as they were originally designed. This meant enacting instruction with little adaptation to account for the setting, technology, or students. Much more time was spent planning for addressing classroom and time management related issues that needed to be addressed to enact the curriculum materials. Offloading the planning of instruction to the curricular and technological materials resulted in limited attention being paid to the role the technology could play in supporting students’ engagement with content.

Tom, on the other hand, worked with an advanced group of students and a teacher who had been in the district for over 15 years. His approach to planning took a much more distributed improvisation approach (Forbes & Davis, 2010), meaning he pulled on a number of curricular resources (text book, simulation, his mentors previous worksheets and problem sets) to design his own lesson around the simulation. This appeared to allow Tom to overcome the difficulties in thinking about planning engaging instruction given the contextual constraints of his school (having to teach any simulation based lesson in a computer lab). Despite this Tom still struggled in using planning practices that focused on communicating expectations to his students about using the technology and in supporting task demand across the lesson. This resulted in his Instructional Performance 2 lesson plan being slightly below the level of planning demonstrated by other PSST.

4.3.2 Contextual Supports

As talked about in section 4.1 Janet and Alice were placed in the same district and had similar technological resources at their individual sites, including a laptop cart in their individual rooms.

Both Janet and Alice were working with mentor teachers who had been teaching in their respective areas for at least 15 years.

In her Instructional Performance 2, Janet planned a lesson about the structure and properties of atoms and compounds. Her learning goals focused on the parts of atoms (protons, neutrons, and electrons), the structure and properties of matter, and differences among atoms and compounds. In Interview 2 Janet noted that, “the most difficult [thing] was finding a technology that fit into the learning goals. That took the longest time for me.” When asked why she thought this work was so challenging, she replied:

> "I think teachers are used to teaching this through direct instruction, like the protons, electrons, neutrons, charge of each of them and how to draw a Bohr model. I think they usually teach it through direct instruction and then practicing Bohr models. So, it was a little hard to find a simulation. It was kind of specific for a simulation for this lesson." (Interview 2)

Despite thinking very hard about finding a simulation to support the learning goals of this lesson, both Janet’s Interview 2 and Instructional Performance 2 lesson plan demonstrated little evidence of thinking about or planning how she would actually engage the students with the simulation. This lack of evidence making explicit how the students would engage with the simulation was despite the fact that his was part of the stated requirements for Instructional Performance 2 (APPENDIX L). Instead, most of Janet’s planning focused on classroom management type issues. When asked about what she focused on in her planning, Janet responded:

> “What technologies were available to us and how the students were going to actually perform the task. So grouping. How much time it would take. Um, how I would assess their knowledge. How I would assess what they got out of the lesson. Hopefully getting at the learning goals. Those were all things I thought about when planning it." (Interview 2)

This quote closely aligns with the “anticipating section” of her lesson plan (Figure 19). Rather than anticipating students’ thinking about the visuals they would encounter in the simulation and the teaching moves that might allow for connection to the learning goals, the lesson plan focused on student and classroom management type strategies.

- Anticipated Responses:

  -Off task behavior, I will address off task behavior as it arises by monitoring the room and having the assistance of the inclusion teacher and sub. I will have what the students are supposed to be doing posted on the powerpoint, so I can have them refer back to what they are doing

  -Not understanding task, I can assist students in making their first element’s Bohr model if groups are still confused. I made groups so that a stronger student will be in each group.

  -I will point out the mass number tab if students are confused about what neutrons do in an atom.

  -Groups not talking, we had a lengthy discussion about working with others but I can remind students that it is sometimes necessary to work with people who are not our best friends.

Figure 21. Janet’s Anticipating Section of Her Instructional Performance 2

It should also be pointed out that this focus on classroom management was something her mentor teacher was pushing very hard for her to think about at the time of her planning this lesson. This clearly had an impact on her planning more so than the general support Janet received in planning engaging lessons with technology (from the pedagogy course sequence and me, her supervisor) and the access to resources she had available at her placement site. In fact, not only did Janet not plan a high demand task for her students, but she also failed to plan to engage her students in any of the science and engineering practices. This stands out in her planning of task, especially since she had always planned for students to engage in at least one

SEP in all of her other submitted lesson plans. Despite this lack of planning for task, Janet did leverage planning practices around the launch of her lesson and in asking her student's questions. Again, a key feature of how these planning practices played out in the instructional Performance 2 is that Janet could focus much of this work on classroom management related issues such as the roles of various students within the class (Figure 22), thus appeasing her mentor teacher.

- I will remind students to write down their group number and role on pg 1 of their handout.
- We will go over what each assigned role should be doing.

Reader: Responsible for the computer (logging in/logging out). Should sit in the middle of the row so everyone can see the computer screen.

Recorder: Responsible for taking notes during the activity, everyone should fill out the packet.

Presenter: Responsible for presenting the material at the end of the activity, should be able to explain your group's answers to each question.

- I will switch to the next slide which has a set of directions for the Computer Reader.

1. Look at Role Sheet at Table
2. Computer Reader, Open computer
3. Log onto your username
4. Go to Google Chrome
5. Go to: http://www.rsc.org/learn-chemistry/resources/phet/build-an-atom_en.html

5. Return attention to front

- I will make sure all students get to the correct website by walking around the room and having the sub/classroom inclusion teacher monitoring the class.
- While this is happening, I will direct the rest of the class to the handout page 2.

Figure 22. Excerpt of the Launch Portion of Janet's Instructional Performance 2

Alice had a mentor teacher who was very supportive of allowing her to teach whatever lessons she wanted using technology. Unlike Janet’s mentor, Alice’s mentor provided very little direction in what she should be attending to in her planning and actual provided little support in that planning process. This was likely a result of her own trepidation in using technology in her classroom for anything other than as a resource for delivering PowerPoint notes. In the second interview, Alice talked about starting with her learning goals and focusing a majority of her planning on the task she wanted the students to engage in.

> "I had learning goals in mind and knew we had to do a simulation lesson. I was exploring simulations and found a PhET one that I really liked…I was really focused on the task and how I wanted the students to interact with this particularly because it was at the beginning of the unit. So I didn't want them to do a lot of calculations with it. I wanted them to just explore the different, I don't know what to call them, the different tabs they could explore in the simulation. So they could see a more practical example with the sandwich making and then look at some reaction building as well." (Interview 2)

Alice leveraged planning practices that attended to supporting students’ engagement in her task. She included specific information in her plan about what students might do (anticipating) and how she might select and sequence their work in a whole class discussion to support the lesson learning goals (Figure 23).

The Tasks:

First task and discussion:

First discussion will be of their response to the limiting reactant question. I anticipate that the students will take a variety of paths and approaches to answer the question by using examples from the simulation. I anticipate that most students will answer this question using the sandwich example because this is something that is more familiar to them. I anticipate the responses to include some of the following ideas: limiting reactant deals with a reactant of the reaction (starting material), the limiting reactant is the reactant that you run out of first, the limiting reactant determines how much product you can make because the reaction stops when this reactant runs out, and I anticipate some diagrams showing this depletion of the reactant. In the discussion, I will randomly choose a student to share their response to this question. After they share, I will choose another student and ask them to respond to the first person's response by identifying one thing that is similar and one thing that is different between their responses. I will do this two more times so that six students end up sharing their responses to the question in the task. I wanted the first task to surround the conceptual understanding of the material presented in the simulation because this will help me get a feel for the students' understanding of the concepts. Additionally, since a big affordance of the simulation is the lack of terminology or conceptual emphasis (ie stoichiometry, identifying things as limiting reactants), this will allow the students to work through this themselves.

Figure 23. Excerpt of Alice's Instructional Performance 2 Task Description

Based on the previous examples it is clear that context had an impact on PSST planning practices. Undoubtedly, in the cases of Courtney, Tom and Janet, their contextual factors (limited resources, inexperienced mentor, level of students, and mentor pressure) played a significant role in the planning practices they decided to leverage in the planning of Instructional Performance 2.

In the case of Courtney, the compounding factors working against her using a simulation seemed to drive her to leverage planning practice focused on behavior management. For Tom, his mentors experience and approach to planning allowed him to ultimately adapt, although with some difficulty, to the lack of school resources as he leveraged planning practices. Janet, in order to appease her mentor, focused her planning practices on areas that overlapped well with the classroom management strategies her mentor had requested she attend. Interestingly she chose to only attend to those practices and not just include them within other practices she demonstrated the ability to use in other assignments. Finally, unlike the other PSST, lack of support from her mentor teacher drove Alice to leverage a number of planning practices as she worked to engage her students in a simulation lesson. It is unclear if this result (leveraging a number of planning practices and really carefully accounting for a number of possible outcomes) was directly influenced by her mentor's trepidation with technology or was just the result of her own planning choices.

4.3.3 Summary

The results presented in section 4.3 suggest that contextual factors did have an impact on the planning practices that the PSST decided to leverage. Specifically, PSST who had greater contextual supports seemed to have more success attending to planning practices aligned with supporting engaged science learning. PSST with contextual challenges attended to far fewer of these practices. However, within the two levels of context there was large variability in the design of instruction between the PSST within those contexts as discussed in the examples of Courtney and Tom in section 4.3.1.

It is clear that the nuances of the internship in which the PSST had to think about and enact their planning had an impact on their choices in planning practices. It is also important to note that not all contextual features seemed to be deciding factors in how PSST designed instruction. For example, although several PSST noted having access to online curricular and text resources in their technology based curricular & site resources assignment, not a single mention of these resources appeared anywhere in their lesson plans or interview data. These results suggest that as teacher preparation programs consider how they are working with PSST they must deliver instruction, resources, and practices that allow the PSST to account for and, in some cases, overcome contextual factors as they attempt to develop PSST ability to plan using technology in support of engaging instruction.

4.4 RESEARCH QUESTION 4: DO PSST ATTEND TO THE SAME OR DIFFERENT CONSIDERATIONS WHEN PLANNING LESSONS INVOLVING COMPUTER SIMULATIONS COMPARED TO LESSONS INVOLVING OTHER DIGITAL TECHNOLOGIES?

Within 2 weeks of the end of the pedagogy course general technology intervention, all of the PSST had completed Instructional Performance 3. In this assignment (APPENDIX M), the PSST were required to include the use of a digital technology in their instruction, however, the assignment did not specify the nature of those digital technologies (e.g. PSST could elect to use computer simulations, graphic software, smart boards, etc.). The PSST showed a shift in their planning as coded on the LPR from their simulation lesson, Instructional Performance 2, to their general technology lesson, Instructional Performance 3. In fact, the dimension scores averaged across all PSST decreased for every category except *task* on the LPR rubric (Table 17). Most notable is the drop on the three technology dimension scores (Technology Worktime, Technology Resources, and TPACK).

Table 17. Average LPR Dimension Scores Across All PSST for Instructional Performance 2 and Instructional Performance 3

	IP2	IP3
Launch	1.93	1.57
Task	0.78	0.89
5P Worktime	1.47	1.17
Technology Worktime	1.21	0.96
Technology Resources	1.17	0.33
TPACK	1.42	0.38
Close	1.39	1.22

Due to the limited sample size statistical analysis were not performed. The goal of table 17 is not to suggest a statistically significant shift in PSST average dimensions scores. The goal, rather, is to demonstrate that despite some shifts in the PSST written planning the PSST still attended to the same planning routines in Instructional Performance 3 as they did in Instructional Performance 2, although in slightly different ways. Regardless of whether it actually showed up in the PSST Instructional Performance 3 planning documents, PSST continued to talk about attending to learning goals, task selection and design, supporting materials, and features of the technology during their Interview 3. In the following sections I present examples of how various PSST addressed the individual planning practice through planning routines in their Instructional Performance 3 lesson plans and Interview 3 data.

4.4.1 Attending to Learning Goals

When discussing her Instructional Performance 3 lesson centered on comparing compounds and elements and the properties of each, Janet talked about how she initially looked for a simulation to use but couldn't find one that aligned with her learning goals. She described specific affordances and constrains that she considered related to the simulations she found:

> "I looked at different simulations too but I didn't really like the ones that I found so . . , They didn't really tie back to the big idea that I was trying to get to. They showed how elements can combine to form compounds and then there was a lot with like balancing equations. But there wasn't any with really what the properties were and I had a couple of videos that I showed them of just different elements coming together like sodium and chlorine are completely different than NaCl. So I showed a couple of videos, but I think that was after this just to reinforce it."

Having investigated the individual affordances of various simulations (e.g. the ability to simulate compound formation), Janet ultimately decided to use excerpts from different videos rather than any single simulation to support those learning goals. Her focus on ensuring that the digital resources were tightly aligned with the big idea and learning goals guided these choices.

There is evidence that 5 of the 6 PSST took up the practice of connecting the technology to their learning goals during planning at this stage of their teacher preparation program. In Interview 3, Tom described selecting a simulation that allowed student to look at the relationships of bodies and force. Alice talked about having students apply learning goals from her unit in new and novel ways. Jay mentioned that he wanted his students to reengage with learning goals that were addressed earlier in the year. Gwen described how she selected an iPad application because it had the potential to support students in exploring cellular respiration and specifically, energy transfer in that process. All of the PSST talked about supporting their students' achievement of specific learning goals for Instructional Performance 3 except Courtney.

Courtney's interview showed her continued struggle with gaining access to technological resources and as a result a difficulty in planning and discussing integrating technology in her instruction. She states explicitly in her interview that she selected her Instructional Performance 3 lesson because it was something another teacher had already done and fit in her unit.

> "So this idea was from another chem teacher in the school. So he did it with his students, so he suggested that we could use it. So he gave me the materials for it."

Across all of interview 3 this was the only instance in which she referenced learning goals. It should also be pointed out that she did have learning goals in her lesson plan (Figure 24).

Learning Goals:
- Spectrums differ in elements due to their different properties.
- A spectroscope with spectral tubes are able to be used to see different spectrums.

Figure 24. Courtney's Instructional Performance 3 Learning Goals

Given the presence of the learning goals in the Instructional Performance 3 but not in her Interview 3 and based on her referencing this being another teachers original lesson, it is fair to assume that Courtney got these learning goals from the other teacher in the school that gave her the lesson, rather than developing them herself. This is not necessarily a bad thing, as part of the work discussed in the pedagogy course sequence is using and adapting other peoples lessons, materials, and even learning goals. However, when asked about how the lesson related to learning goals, Courtney responded with an explanation of what the students would be doing in the activity.

> "So what the students were going to do was they were going to go into the labs and look at rays through a hand held spectroscope and see the different wavelengths from different elements as well as from florescent and sunlight and a light bulb."

This structure of thinking about these connections in terms of describing what students will be doing instead of what they will be thinking about was a departure from how the other PSST approached this work. In fact, all of the other PSST really centered and focused their thinking about their planning on the learning goals they hoped students would develop over the course of their lessons. In Interview 3 Gwen was asked about what she focused on in her planning of the lesson. Her response is concise, yet representative of the other 4 PSST who attended to this planning routine:

> "I think definitely the learning goals and how I would get the students to reach those learning goals. And how I would incorporate the iPads and the app into helping them achieve that learning goal. And also how I would kind of fit the app into the lab that they would be doing as well. How they would go hand in hand or run right into each other." (Interview 3)

4.4.2 Attending to Task Selection and Design

Similar to Interview 2, all of the PSST leveraged the planning routine of attending to the tasks students would be engaging in during their planning in Interview 3. All but one PSST, Jay, planned low cognitive demand tasks. Despite this, all but one PSST demonstrated a focus on thinking about tasks that got students to engage with the technology in ways that related back to their learning goals. In Figure 25 we see the portion of Janet's lesson plan that focused on talking about how her students would use the QR codes, iPads, and websites to find information to answer the question she posed in their task packet about the difference between the properties of compounds and elements.

iPAD Research and Worksheet (9:40-10:00)

- Read over directions.
- iPADS
- What is a QR code?

ELEMENTS http://education.jlab.org/itselemental/

COMPOUNDS http://pubchem.ncbi.nlm.nih.gov/

Okay, now we are going to talk about our iPAD research. So when you read over the directions at the beginning of class (or give them a minute to read the directions if they straggled in late) what questions did you have?

I anticipate students will have questions about the QR code part. We are going to go over how to use this as a class. I want the first row to come up and get iPADs, second, third.

We are going to go over how to use a QR code, it is really simple and pretty cool. All you have to do is go to the app that looks like a barcode on your iPAD called QRreader. You hold the iPAD up to your paper and align the box with this funny look box and it will take you to the website I suggested.

I added the websites URLs to the Powerpoint just in case the QR code did not work. If students can't get to the website I will have them use Safari to type in the URL.

I will make sure all students get to the website they need to before I give the next set of directions.

So listen to directions for another moment. I want you to use this website to research your element or compound and answer the worksheet in your packet. The website might have some words you don't understand and that is fine, I don't expect you to know all the words. However, look for some words you do recognize and only write down the things you can understand and later explain to the class. I will be around to help you so don't panic. You can use other sources, but make sure you use a .gov or .edu site and write down the source you used .Any questions?

Figure 25. Janet's Technology Task Directions

When asked about what she focused on in her planning in her Interview 3 Janet said that :

> "I really tried to focus on how students were going to try to interact with their iPads and their groups. I had a lot of anticipation about problems that could arise"

This planning practice of anticipating students' responses was something that appeared in multiple PSST planning routines of attending to task selection and design. In her Interview 3 Alice talked about the need to engage her students in work that fell outside of their typical problem solving norms. She set out to have her students participate in an Apply portion of a learning cycle, where they would use the knowledge and skills they had already developed around stoichiometry over the course of the unit to answer a set of complex real world problems. In the following excerpt (Figure 26) from Alice's Task portion of her Instructional Performance 3, she highlights her reason for selecting this task and a small bit of anticipating students' reactions to the task.

The Task:

Today's task will consist of two different real-world based problems that use their stoichiometry skills they have developed thus far in this part of the chapter. The problems will be challenging for the students because they will have to pull together these different stoichiometry skills rather than being explicitly directed in the problem (ie how many moles of x do you have if you have ___ ions of x?). Additionally, I will push the students to explain their work, challenging them to examine why they are doing each step rather than just simply allowing them to show their work. This will also work on accountability for the students as they may be forced to explain in front of the class.

While working with the two problems, I anticipate that the groups will take a wide variety of approaches in solving the problems. I also anticipate that many groups may feel overwhelmed at first when they are looking at the problem, so I will be ready to scaffold and provide supports so that they can access these problems. I have detailed some anticipated concerns in the "challenges and misconceptions" section of this lesson plan.

Figure 26. Excerpt of the Task Selection Portion of Alice's Instructional Performance 3

4.4.3 Attending to Supporting Materials

Similar to Instructional Performance 2, Tom went well above his fellow PSST in the work he put into designing materials for his students to use in his Instructional Performance 3 lesson. In the following excerpt from Interview 3 Tom explains the process of creating his lesson and materials.

> "Probably really thinking deeply about how the technical issues were going to come about. So when I did this lab what I had done was I knew the kind of lab I wanted to do. I knew the sensors I wanted to do to accomplish that. I had a really good idea of what it

> was going to look like in my head and for help on how to structure the actual activity, which would be here (points to LP). I went onto the Vernier site and looked at what resources they had for the specific sensors for both the motion and the force sensors and looked at the activities they and adapted what they had. Rewrote it in my own words and my own spin on the questions and fit them to my own class. So I think the most challenging part of that was sort of, I would say making the lab activity and figuring out how I could sequence questions and where the data gets collected in terms of the sequence of the activity so that it scaffolds that concept of well what didn't we have last time that we did this that we need to get to discuss it successfully and sequencing that was probably the most challenging." (Interview 3)

Although Tom was an extreme case, in that he used a very distributed improvisation approach in his planning, all of the other PSST at a minimum adapted materials to fit their specific students' needs. This was again seen in all of the PSST Instructional Performance 3. As an example, Figure 27 shows a portion of the adapted lab that Gwen designed to allow her student to collect the data they needed to investigate cellular respiration.

Procedure:

1. One student will be the timer and the other will be the participant. **After the student has performed all activities, you will switch roles**
2. Fill each test tube ½ full with water
3. Add BTB, to one test tube, one drop at a time, stirring with a straw. Count the drops as you add. Stop when the water changes blue (it should be about 10 drops)
4. Add the same amount of BTB to each test tube. Stir with a straw
5. Put a straw in one of the test tubes once you have finished stirring.
6. Measure the rate of your partners cellular respiration after the following activities:
   a. After sitting calmly and quietly for 2 minutes
   b. After laughing for one minute
   c. After jogging in place for 2 minutes
   d. After doing 25 jumping jacks
7. Immediately after performing the activity, the participants will blow into the straw turning the BTB/water to yellow as the timer records the time it takes for the change in color.
8. Record data in chart below.
9. You will each complete one trial and get an average of both.

Activity	Trial one (time)	Trial two (time)	Average time
Sitting Still			
Laughing			
Running In place			
Jumping Jacks			

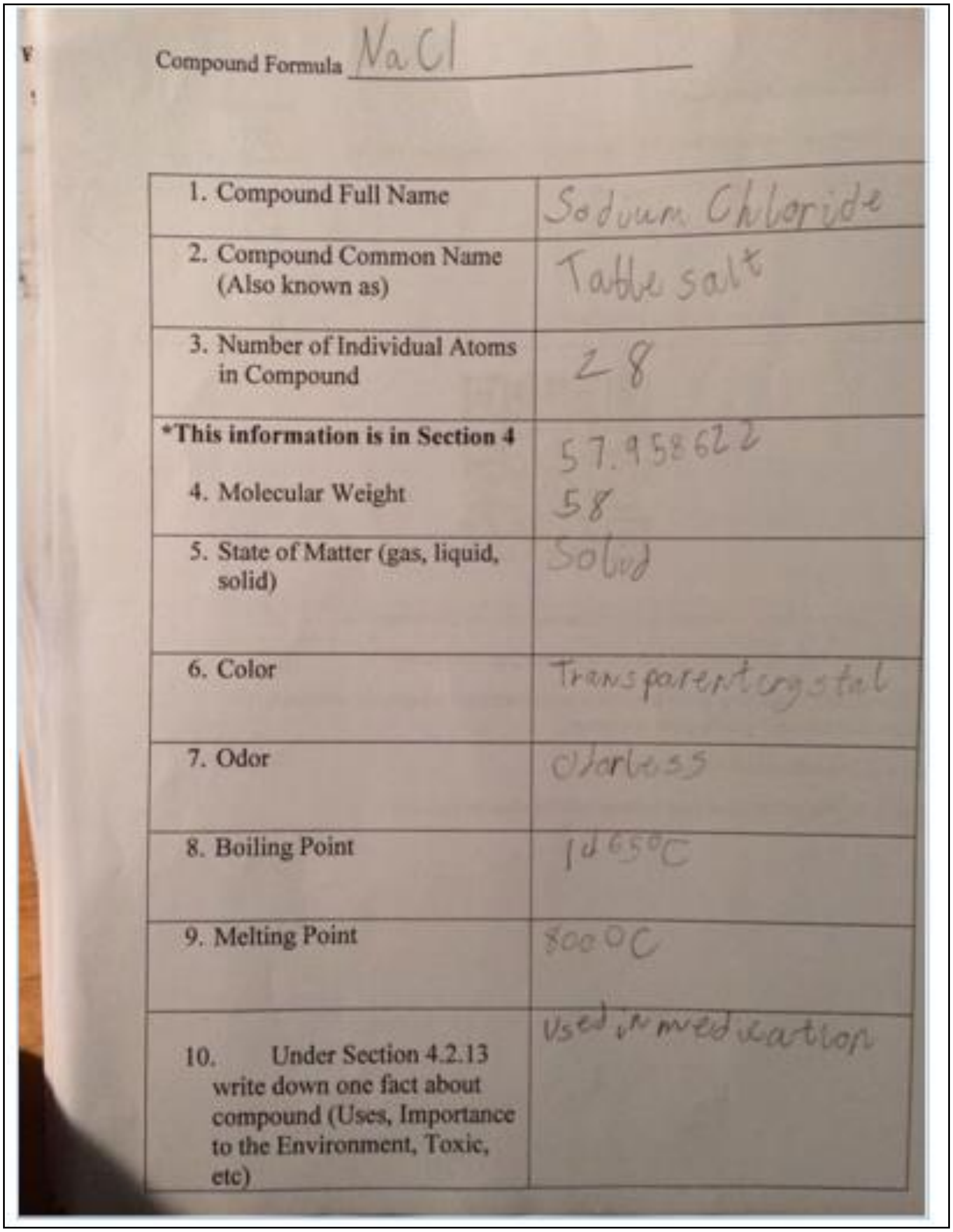
Use the average to prepare your evidence based explanation*

Questions:

1. What activity produced the highest rate of cellular respiration?
2. Did your results agree with your hypothesis? Explain
3. What happened to CO2 production as you increased exercise?
4. What happens to your energy needs as you exercise more?

Figure 27. Gwen's Adapted Lab Procedure, Data Table, and Questions

This adapting of labs and handouts was seen in all of the PSST Instructional Performance 3, despite the sometimes low level of demand associated with the resources. For example, Janet adapted a handout (Figure 28) previously used by her mentor to support her students' exploration of different websites as the students investigated the different properties of compounds and elements.



Compound Formula NaCl

1. Compound Full Name	Sodium Chloride
2. Compound Common Name (Also known as)	Table salt
3. Number of Individual Atoms in Compound	2 8
*This information is in Section 4 4. Molecular Weight	57.958622 58
5. State of Matter (gas, liquid, solid)	Solid
6. Color	Transparent crystal
7. Odor	Odorless
8. Boiling Point	1465°C
9. Melting Point	800°C
10. Under Section 4.2.13 write down one fact about compound (Uses, Importance to the Environment, Toxic, etc)	Used in medication

Figure 28. Janet's Instructional Performance 3 Adapted handout

The clear expectations of the information that students were required to report out lowered the task demand by not allowing the students to determine the important information and form justifications for those decisions. Despite the lowering of the demand, the material she adapted supported her specific students and the time constraint of her class in getting the students to quickly and efficiently collect the information she thought would be important for the class discussion the following day.

4.4.4 Attending to Features of the Technology

Only Alice addressed the ideas of affordances and constrains in support of student engagement in her Instructional Performance 3 lesson plan. Despite this, when asked to talk about how they considered these factors in their interviews, 5 of the 6 PSST elaborated in great detail about the process they engaged in around affordances and constrains. In his interview Jay talked extensively about the affordances and constraints of the simulation he selected to use for his technology lesson.

> "in service of the learning goals I wanted them to see the relationship between the position, velocity and acceleration and having them have graphs produced all along the same axis really allows for that easily. Retaining the graphs, that's huge. They don't just disappear when you stop the simulation from running. not having to many extraneous features means that hopefully they stay on task more" One of the constraints that he talked about was that "there were times when my position graph went off the top of the page and you couldn't see it anymore…" (Interview 3)

Tom, in his interview, talked about how the lab probes he selected were in part based on student familiarity with the tool and also because "The lab quests are nice technology of data collection software with minimal user interface. This helps limit problem data."

Alice also considered the affordances of her technology, specifically the ability for students to quickly share their work with the class and be able to explain their process for solving the problem while showing specific steps of their work without having to rewrite the information on the board. In this quote from her Interview 3 Alice talks about the affordance and how she was thinking about its relationship with the way she was going to structure her task and discussion.

> "I decided I was going to have them, different groups, come up and show their work with the advantage and affordances that you could just get up with their paper without having to rewrite it on the board and cut out that time. But, like, what I wanted that to look like. Their used to coming up and writing their work on the board and explaining it as they did that. So it was already done. Having them actually just explain it. How I wanted to do that." (Interview 3)

4.4.5 Summary Across the Planning Routines

Looking across the data (Instructional Performance 2, Interview 2, Instructional Performance 3 and Interview 3) two things stand out. First, almost all of the PSST leveraged the same planning routines from the simulation based Instructional Performance 2 to the general technology Instructional Performance 3. Second, although PSST attended to the same planning routines across both technology based assignments, the way in which they did this work changed slightly. Some individual PSST seemed to shift the planning practice that they used in the various planning routines. This shift in leveraging different planning practices suggests that the PSST have a very developed understanding of the practices and how they want to utilize them. The PSST seem to be focused on attending primarily to the four planning routines; however, for each individual lesson some of the contextual and context factors change. Thus, in order to attend to the same planning routines, they must leverage different planning practices in order to accomplish the same goals associated with the practices. I contend that this ability to pull on individual practices in support of the various routines is a critical feature of pedagogical design capacity for technology and demonstrates a well-developed understanding of these practices and routines for PSST.

The emergence of this pattern of PSST focusing their instructional planning around a set of planning routines rather than individual practices is an unexpected outcome of this study. It suggests a different developmental trajectory of how PSST think about planning engaging instruction supported by technology and forces a possible reconceptualization of how PDC, specifically PDC for technology, is developed and leveraged. I discuss the ramifications of these results on PDC in section 5.1.

4.5 RESEARCH QUESTION 5: DO PSST DEMONSTRATE PATTERNS OR CHANGES IN THEIR PLANNING AROUND DIGITAL TECHNOLOGIES OVER TIME?

In this section, I report the PSST data from across the study including average and compiled data from the Lesson Plan 1, Lesson Plan 2, Instructional Performance 1, Instructional Performance 2, Instructional Performance 3, Scenario 1, Scenario 2, Scenario 3, Pre TPACK Self-Assessment, and Post TPACK Self-Assessment. Given the limited sample size, the data reported in this section is not intended to be generalizable to the larger population of PSST. Instead, the data in this section is intended to highlight the development of these specific students across this specific pedagogy course sequence. The goal of reporting out this aggregate longitudinal data is to give a picture of the process these PSST went through in planning with digital technology over the course of this study and provide insights on the development of future work. Ultimately the data is presented as a way to interrogate how these PSST ability to plan and think about the use of technology in instruction changed over the course of the pedagogy course sequence and is meant to act as a pilot for future work.

4.5.1 Lesson Plan and Instructional Performances

Although all of the Lesson Plan and Instructional Performance assignments were submitted for grades as part of the pedagogy course sequence, only the Instructional Performance assignments required the PSST to actually carry out instruction at their internship site. Looking at the general trend of performance on the LPR for each assignment averaged across PSST we see a steady increase in scores from Lesson Plan 1 through Instructional Performance 2 (Figure 29). The data show that as the PSST progressed through their pedagogy course sequence their ability to write lesson plans that were aligned with practices associated with engaging instruction, as outlined by the NGSS and measured on the LPR, improved. This continual improvement was followed by a dip in the average PSST LPR score on Instructional Performance 3.

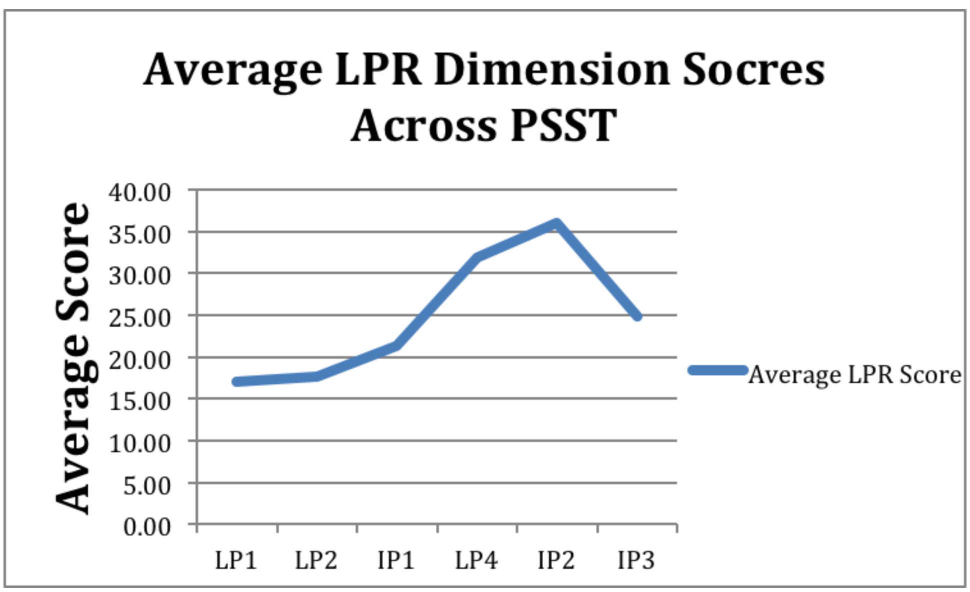


Figure 29. Average LPR Codes Across Collected Data

In Figure 30 the LPR scores for each individual assignment are graphed for each PSST. This representation allows for the individual progression of each PSST to be compared with the overall trend from Figure 29. The graph shows each individual PSST progression over the course of the assignments that were coded using the LPR, with Lesson Plan 1 being the earliest assignment placed on the left and Instructional Performance 3 the last assignment placed on the right.

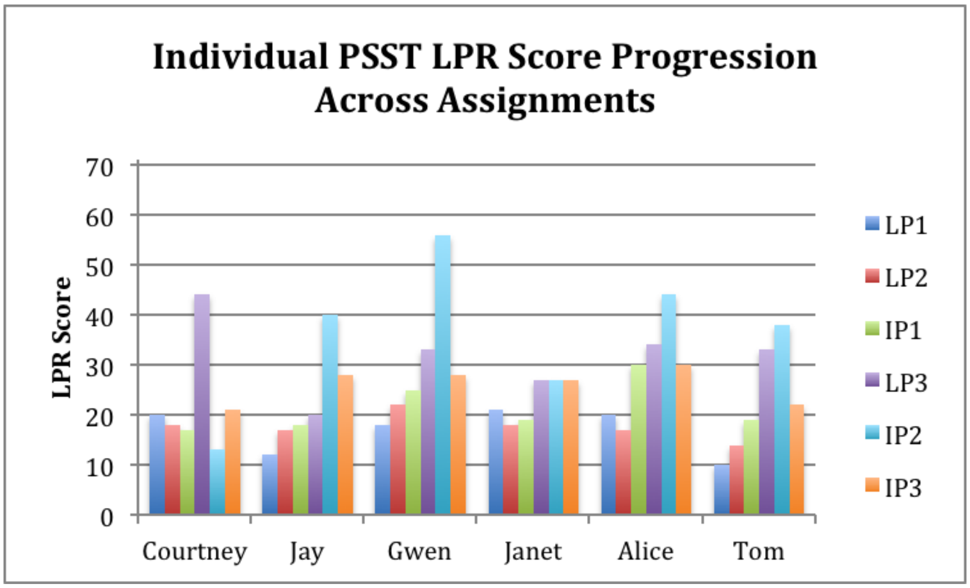


Figure 30. Individual PSST Lesson Plan Rubric Score Progression Across Assignments

Two important trends are noticed looking across the data represented in Figures 29 and 30. First, Instructional Performance 2 was an apex for 4 of the 6 PSST written plans as coded by the LPR. As discussed in section 4.2.1, this represented a culmination of work related to using simulations in the pedagogy course sequence. It isn't necessarily surprising to see the PSST scores improve from the beginning of the program to this point. Not only are they gaining the skills associated with thinking about and planning engaging instruction they are also developing the skills associated with writing lesson plans.

Second, 5 PSST showed a drop in LPR score from Instructional Performance 2 to Instructional Performance 3. As discussed in section 4.4, the PSST were asked to engage in many other planning practices that were tangential to the work of planning engaged science instruction with digital technology during the intervening time of these assignments. This shift in focus appeared to result in a shift in PSST written planning away from the previously developed practices as coded on the LPR. This shift away from the use of previously observed planning practices in PSST written lesson plans is something discussed in previous work (Ross, 2014). Unlike previous work, the paring of this written data with interview data focused on these written lesson plans suggests a slight disconnect between the thinking PSST are actually doing during planning and the written product of that thought process. Specifically and as discussed in section 4.4.5, the PSST maintained a focus on thinking about planning practices as they went about their planning of Instructional Performance 3. This disconnect suggest the need for further investigation of how students written plans are actually related to their thinking during planning and the impact this has on enacted instruction, as discussed further in section 5.2.

4.5.2 Simulation Scenario Assignments

Although all PSST completed all three of the Simulation Scenario Assignments as part of the pedagogy course sequence, these assignments were not actually graded as part of their course grade. PSST were given 48 hours to complete each of the Simulation Scenarios with all of them submitting responses on time. Looking at the performance on the SSR for each of the three assignment averaged across PSST we see an improvement in scores from Simulation Scenario 1 to Simulation Scenario 2 with a dip in Simulation Scenario 3 (Figure 31). The Simulation Scenario 2 assignment score represented a shift in the PSST ability to answer the scenario questions in relation to making connections across the TPACK dimensions as measured by the SSR as compared to Simulation Scenario 1. In Simulation Scenario 3 the score was lower than Simulation Scenario 2, yet larger than Simulation Scenario 1. Despite this slight shift backward in the PSST ability from Simulation Scanario 2 to Simulation Scenatio 3, the PSST still scored higher on the SSR toward the end of the program than at the beginning. This trend mirrors the results seen in the trends of the Instructional Performances discussed in the previous section.

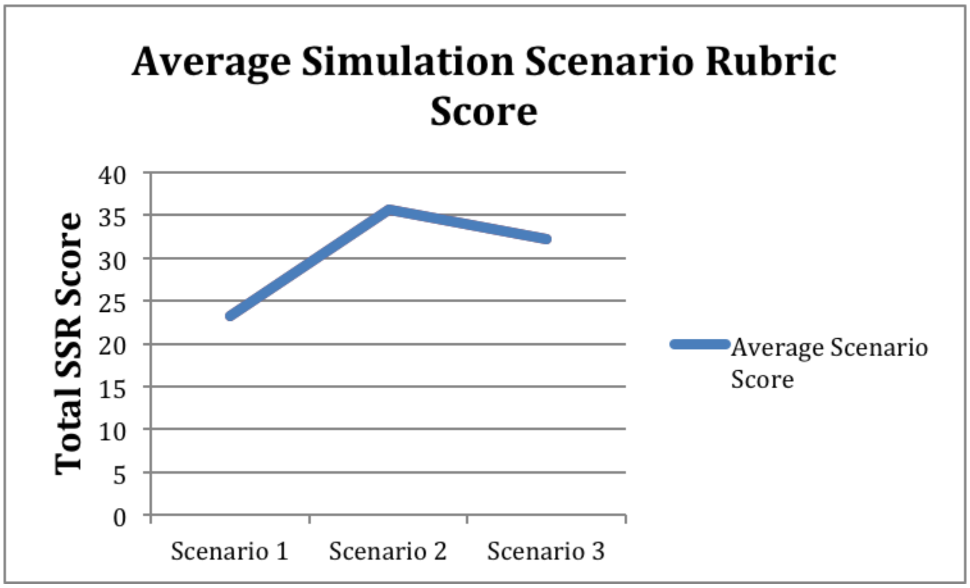


Figure 31. Average SSR Score for Each Scenario Assignment Across Collected Data

To understand how individual PSST compared to the average Simulation Sceanrio Rubric trends, Figure 32 represents the individual progressions of each PSST Simulation Scenario assignemnt SSR scores. For each PSST the Simulation Scenario 1, 2, and 3 are represented as going from left to right in chronological order.

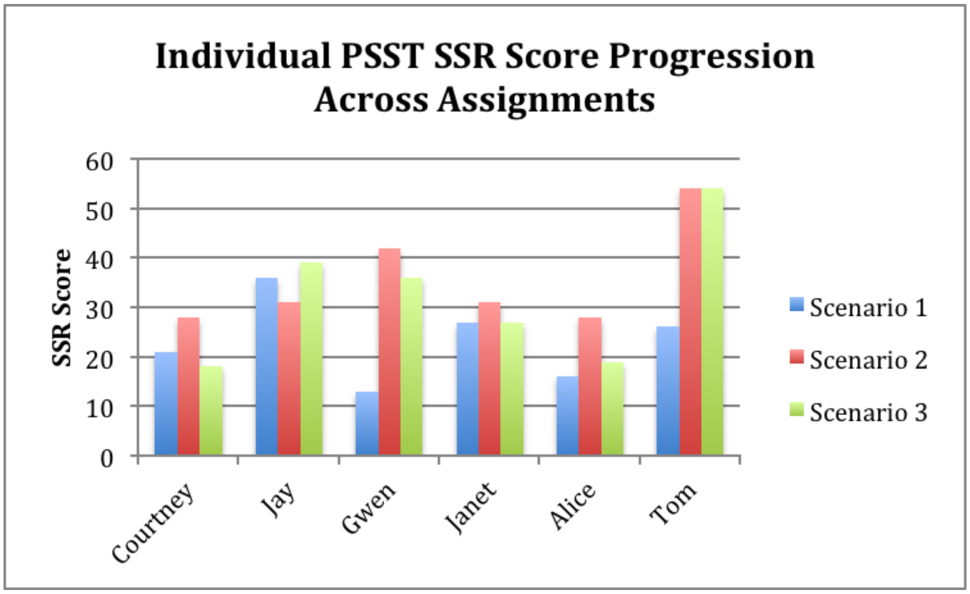


Figure 32. Individual PSST Simulation Scenario Rubric Score Progression Across Assignments

All but one of the PSST, Jay, showed an increase from Simulation Scenario 1 to Simulation Scenario 2. This shift for most of the PSST is likely a result of the timing of when the Simulation Scenarios were administered in the pedagogy course sequence. Simulation Scenario 1 was administed just after the PSST had completed the pedagogy course sequence on engaged science learning. Little work had been done around supporting tasks with pedagogy or around technology. This truly was a way to assess the PSST TPACK and thinking about planning prior to intervention in the pedagogy course. Simulation Scenario 2 was administerd after the PSST had completed all of the pedagogy course sequences around the 5 Practices along with the simulation intervention. The fact that scores increased does not necessarily come as a surprise given this context. However, what is notable is how well Jay and Janet did on the Simulation Scenario 1 and the limited change in their scores over time on the SSR. This suggest that something about these PSST previous expereicnes, either prior to the program or in their placement, allowed them to perform well on the first assessment.

Four of the six PSST showed a decrease from Simulation Scenario 2 to Simulation Sceanrio 3. Similar to the drop seen between the LPR scores from Instructional Performance 2 and Instructioanl Performacne 3, this drop is likely the result of the shift in focus in the pedagogy course sequence. Finally, 5 of the 6 PSST, had a Simulation Scenario 3 score higher than their Simulation Scenario 1 score indicating an overal growth in the PSST TPACK as assessed on the SSR.

4.5.3 Pre-Post TPACK Self-Assessment

The pre-TPACK self-assessment was administered to the PSST prior to the beginning of the engaged science learning section of the pedagogy course sequence. The post-TPACK self-assessment was administered during the first pedagogy course class of the spring semester after the students had completed the entire pedagogy course sequence as described in chapter 3. PSST were given as much time as they needed to complete both the Pre and Post assessments, taking anywhere between 10 and 15 minutes. Table 18 reports the average mean score for the PSST TPACK self-report pre and post survey for each knowledge dimension described in the TPACK framework. Included in Table 18 are the associated standard deviations for each value, along with the number of data points used ("n =") in calculating the mean and standard deviation for that dimension. Finally, the p-values for a matched group t-test are reported in the final column.

Table 18. Average Pre-Post TPACK Dimension Scores With Standard Deviation

	Pre Mean	Pre SD	Post Mean	Post SD	p Value
Technological Knowledge n=42	3.571	0.737	3.929	0.745	0.003
Content Knowledge n=24	4.333	0.565	4.458	0.509	0.377
Pedagogical Knowledge n=42	3.381	0.825	3.548	0.633	0.323
Pedagogical Content Knowledge n=18	3.750	0.897	3.833	0.761	0.627
Technological Content Knowledge n=24	3.292	1.083	3.667	0.963	0.034
Technological Pedagogical Knowledge n=30	3.700	1.022	4.267	0.521	0.003
Technological Pedagogical Content Knowledge n=48	3.375	1.142	3.708	0.713	0.041

The average mean scores for the pre assessment showed that overall the PSST demonstrated a very positive belief (any score above 3) on the 7 dimensions of TPACK. They felt most strongly about their content knowledge (M=4.33). Also, notable in Table 18 is that the post mean scores all increased from the pre mean scores. The two largest increases came in the Technological Knowledge (Pre-3.57, Post = 3.92) and Technological Pedagogical Knowledge (Pre- 3.70, Post – 4.27) dimensions. These shifts indicate a growing confidence in the PSST around their own knowledge about technology and their ability to think about how technology can impact their pedagogical practice.

In order to better understand how individual PSST progressed across these dimension Table 19 shows the individual PSST dimensions scores, averaged across the related dimension questions. The table also reports if that individual dimension score fell within one standard deviation, above one standard deviation “+1”, or below one standard deviation “-1”. Above one standard deviation is marked in green. Below one standard deviation is marked in red.

Table 19. Individual Pre-Post TPACK Dimension Scores with Related Standard Deviation

Courtney	TK	3.428571429	in	3.285714286	in
	CK	4.25	in	4	in
	PK	3.428571429	in	3.714285714	in
	PCK	3.5	in	3.75	in
	TCK	3.25	in	3.5	in
	TPK	4.4	in	4.2	in
	TPACK	4.125	in	3.625	in

Jay	TK	3.714285714	in	4.285714286	in
	CK	4.75	in	5	"+1"
	PK	3.571428571	in	3.714285714	in
	PCK	4.5	in	4.5	in
	TCK	4.5	"+1"	4.75	"+1"
	TPK	3.6	in	4.6	in
	TPACK	4	in	4.25	in

Gwen	TK	2.857142857	in	3.285714286	in
	CK	4.25	in	4.5	in
	PK	2.285714286	"-1"	3.714285714	in
	PCK	3.25	in	3.75	in
	TCK	2.5	in	3.75	in
	TPK	2.6	"-1"	4	in
	TPACK	2.125	"-1"	3.75	in

Janet	TK	3.428571429	in	4	in
	CK	4	in	4.25	in
	PK	4.142857143	in	3.285714286	in
	PCK	3.5	in	3.25	in
	TCK	3.25	in	3.5	in
	TPK	4.2	in	4.2	in
	TPACK	3.5	in	3.875	in

Alice	TK	3.857142857	in	4	in
	CK	4.75	in	4.5	in
	PK	3.428571429	in	3.857142857	in
	PCK	3	in	3.25	in
	TCK	2.25	in	2.25	"-1"
	TPK	3.2	in	4.2	in
	TPACK	2	"-1"	3	in

Tom	TK	4.142857143	in	4.714285714	"+1"
	CK	4	in	4.5	in
	PK	3.428571429	in	3	in
	PCK	4.75	"+1"	4.5	in
	TCK	4	in	4.25	in
	TPK	4.2	in	4.4	in
	TPACK	4.5	in	3.75	in

Gwen showed the greatest change from pre to post. She went from being one standard deviation below the mean in three dimensions to being within one standard deviation on all dimensions on her post. This represents a big shift in her self-reported level of knowledge for these dimensions. As Gwen was the only student to start off with her dimensions scores in the primarily negative level, such an increase demonstrates a major shift in the only PSST who really had a large amount of improvement available across multiple dimensions.

All six of the PSST saw a positive change in at least three of their seven dimensions of TPACK from pre to post. In total 29 of the 42 individual PSST dimensions measured showed an increase, 10 of 42 showed a decrease, and 3 of the dimension scores were unchanged from pre to post.

Of the 10 decreases in dimension score only two had a fall of more than one standard deviation. The first was Tom who went from one standard deviation above on his Pre Pedagogical Content Knowledge to only being within a standard deviation Post. Although this does represent a slight shift, his overall post score is still on the very high end of the positive scale.

The other negative trend was seen in Alice's Technological Pedagogical Knowledge. Alice went from being within one standard deviation on her technological pedagogical knowledge score pre to being one standard deviation below on her Technological Pedagogical Knowledge post; however, this was the result of the group mean changing. Her raw mean score for Technological Pedagogical Knowledge from pre to post was unchanged.

4.5.4 Summary

Looking across the Lesson Plan and Instructional Performance data the PSST showed a positive development in their ability to support engaged science learning, as measured on the LPR, from the beginning of the pedagogy course sequence to the end. The PSST did show a slight regression from their high LPR scores immediately following the Simulation Assignment to the final assignment at the end of the semester. This trend and the overall progression match previous research (Ross, 2014) using similar methodology and rubrics. Similar to this previous research, the PSST trend tightly matches the focus of the course sequence, with the drop in PSST LPR scores coming after the introduction of other instructional ideas in the pedagogy course sequence.

Using an adapted version of a self-report assessment of TPACK, previously tested and verified (Schmidt et al., 2009; Perkins & Scott, 2014), the PSST reported overall positive views of their own knowledge to teach using technology. The results of this assessment differ from previous research (Perkins & Scott, 2014) in that the PSST scored very high on the Pre-Assessment. This high pre score is likely the result of the PSST in this study having already completed undergraduate degrees and most having had previous experience leading or teaching classes at some level (undergraduate, afterschool tutoring, and summer programs). Regardless of the cause, the fact that all of the PSST either maintained or increased their positive views of their own knowledge around teaching suggest that the PSST were supported to think about the work associated with this knowledge in the pedagogy course sequence. Although this sample was limited the data suggest further investigation is necessary around how these assessment results are associated with or linked to actual implementation of the engaged science learning that the assessment hoped to capture. In other words, are PSST self-reported knowledge associated with implementation of engaged science learning what instruction is actually enacted in the classroom.

Throughout this chapter I have reported the results for each research question. In the final chapter I will discuss these results implications for how the field thinks about Pedagogical Design Capacity and outline a set of future work that should result from this study.

5.0 GENERAL DISCUSSION AND CONCLUSION

In the secondary science teacher certification program in which this study was situated, PSST were encouraged to approach their work as instructional engineers. Using this metaphor of engineering as a backdrop, a primary goal of the program was to develop the PSST ability to design instruction that leverages digital technologies to support secondary science students engagement in science learning as put forward in the *Next Generation Science Standards* (NGSS Lead States, 2013). This vision of engaged science learning was developed through a series of pedagogy course lessons designed to teach planning practices. PSST were provided opportunities to engage as learners and teachers in a series of representations, decompositions and approximations of planning practices (Ross, 2014; Grossman et al., 2009). The first set of lessons that the PSST participated in had previously been shown to build PSST capacity to plan instruction centered around cognitively demanding tasks (Ross, 2014; Cartier et al., 2013; Smith & Stein 2011). Specifically, this sequence had been shown to build capacity for planning instruction that uses the Five Practices for facilitating task-based discussion model as a way to engage students in SEP as described in the NGSS (Ross, 2014; Cartier et al., 2013; Achieve, Inc, 2013).

Upon completion of this lesson sequence PSST engaged in an intervention that focused on the use of technology in support of this model of engaged science learning. In this intervention, PSST were able to identify, discuss, rehearse, implement, and reflect on key planning practices associated with using technology (leveraging affordances associated with the learning goals, engaging students with technology in productive ways, constructing high demand tasks supported with technology, etc.) (Grossman et al., 2009). At certain points throughout this intervention and after its completion, the PSST were asked to consider the content, context, and students at their internship as they planed instruction. Engaging in such interventions and design work required the PSST to both develop and leverage their Pedagogical Design Capacity (PDC) (Brown, 2009).

The goal of this study was to understand the development of that capacity as PSST progressed through their teacher preparation program. To develop this understanding, the PSST Lesson Plan, Instructional Performance, and Simulation Scenario Assignments, in combination with their Interview and TPACK Survey data, were examined. Looking across this data for PSST planning practices, knowledge dimensions, and contextual factors allowed for an interrogation of the PSST PDC development over time.

The findings presented in chapter four suggest that, overall, the PSST developed the capacity to plan engaging science lessons that used digital technologies. In developing this capacity, the PSST first developed individual planning practices. These practices were leveraged in combination by the PSST as planning routines. These routines in turn were the primary focus of most PSST planning with digital technologies. This suggest that these routines are a primary piece of the PSST pedagogical design capacity, and are in fact something that can be developed through support, such as the pedagogy course intervention. In section 5.1 I discuss the connection between results presented in chapter 4, how novice teachers and expert teachers act, the process of increasing Pedagogical Design Capacity, and how the development and use of planning practices might figure into PDC and the development of expert teachers. In Section 5.2

I explore next steps based on the results of this study. Finally, section 5.3 summarizes the overall results and contributions of this study to the field.

5.1 DEVELOPMENT OF PLANNING ROUTINES IN PSST: A PART OF PEDAGOGICAL DESIGN CAPACITY DEVELOPMENT

The data from this study demonstrates that as PSST, early in their pedagogy course sequence, engage in the work of designing instruction they begin by leveraging specific and individual planning practices. These planning practice involve PSST thinking about and doing some fine grain level of work that allows for the use of an instructional resource in order to support a specific portion of their design of engaging science instruction. In this sense, instructional resources include things like curricular resources, class context, school context, standards, student prior knowledge, PSST content knowledge, and TPACK, just to name a few. Put simply, instructional resources consist of any physically or mentally constructed resources that pertain to the part of instruction being designed. Figure 33 is an example of how these instructional resources might be brought to bear through the use of planning practices in the design of a specific portion of instructional planning (Design of Lesson Launch Plan).

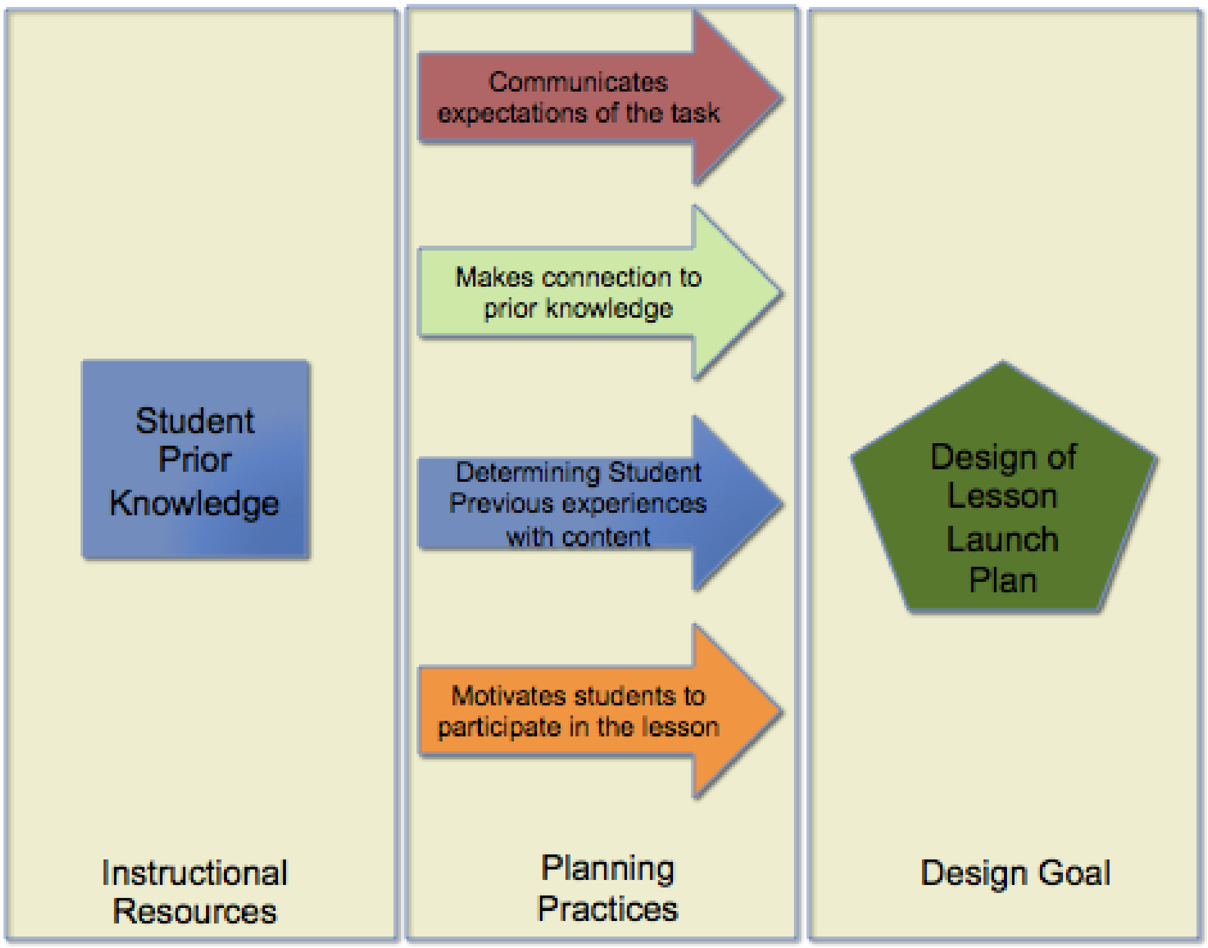


Figure 33. Example of Instructional Resources and Design Purpose Connected by Planning Practices

The example in Figure 33 shows how a PSST would need to utilize multiple planning practices (communicating the expectations of the task, making connection to prior knowledge, etc.) in order to bring to bear the instructional resource (Student Prior Knowledge) in the design of the lesson launch plan. The ability to consider instructional resources, design instruction that takes into consideration how these resources can be used in specific situation, and follow through on that design is at the core of what Brown defines as Pedagogical Design Capacity (2009). In her work in outlining Pedagogical Design Capacity for planning task based discussions, Ross points out that PSST had a tendency to focus on using individual planning practices when thinking about instructional resources as a way to minimize the distractions presented by their context and limited experiences (2014). She suggest that the use of these planning practices in combination represents the pedagogical design capacity for planning task based discussion lessons as visualized in Figure 34.

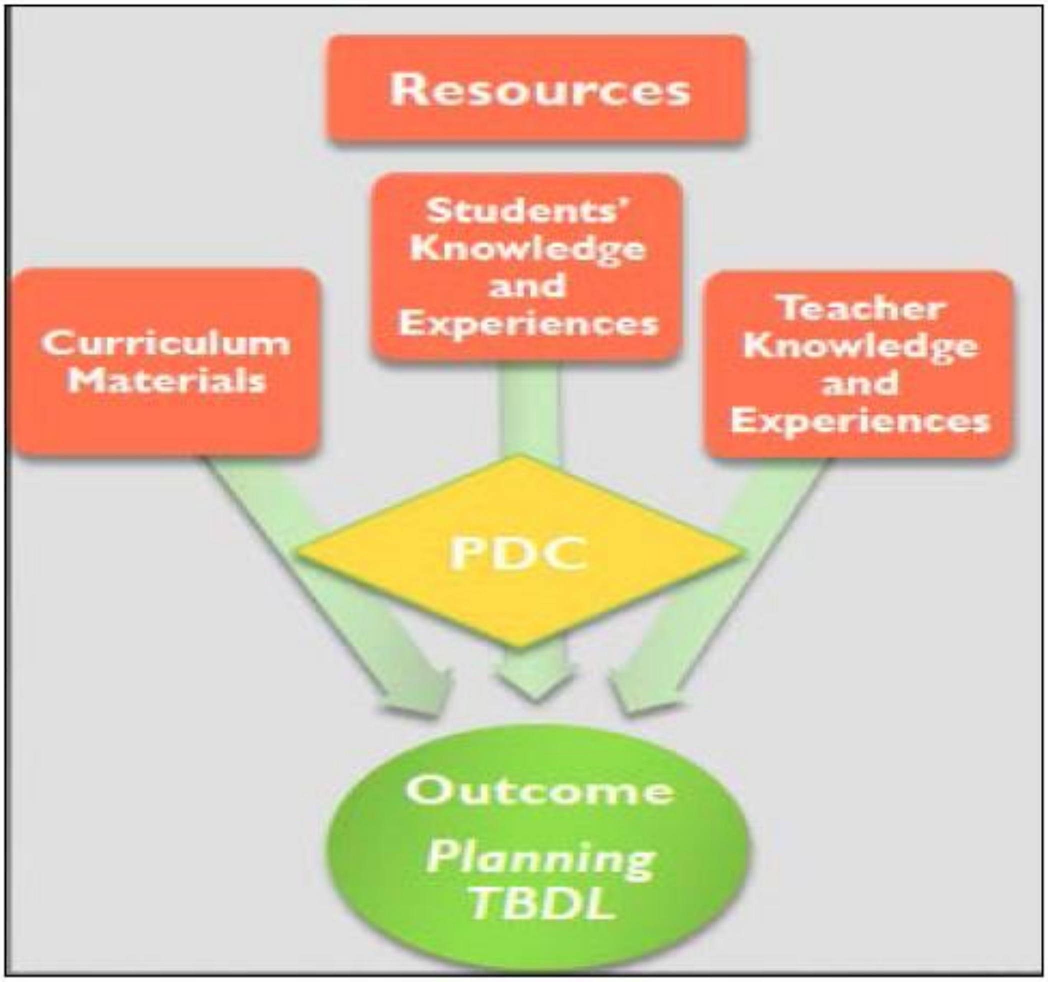


Figure 34. Ross's Model of Pedagogical Design Capacity

From previous work, and supported by the data from this study, we know that the work of leveraging instructional resources by using planning practices can be very complex work for novice teachers and that they have a tendency to ignore or not utilize practices when they feel overwhelmed (Ross, 2014; Kessler & Cartier, 2014). To try and mitigate this complexity, and help PSST understand how to affectively use these practices, the teacher preparation program that was the focus of this study utilized the Grossman and Colleagues framework for teaching practices (2009).

As discussed in section 3.2.3, this framework decomposes practices and builds PSST abilities to understand and work with them through a series representations and increasingly more authentic approximations. The goal was to prepare PSST so that, by the time they had to actually fully design instruction on their own, they were prepared to leverage these practices. The results of how the PSST in this study transitioned from less to more authentic work demonstrate an inability to continue attending to multiple planning practices. These results align with past research that shows that novice teachers have a limited ability to think about and leverage different practices (Ross, 2014).

As an example, if we take Figure 35 and include just two instructional resources, we see the complexity that the PSST must attend to in their design of the lesson launch. Figure 35 provides a visual representation of what considering only 2 instructional resources with 4 planning practices each would look like for a PSST. Now think about the complexity of this process if the PSST is responsible for considering multiple instructional resources for each section of the design of instruction they are responsible for in a given lesson.

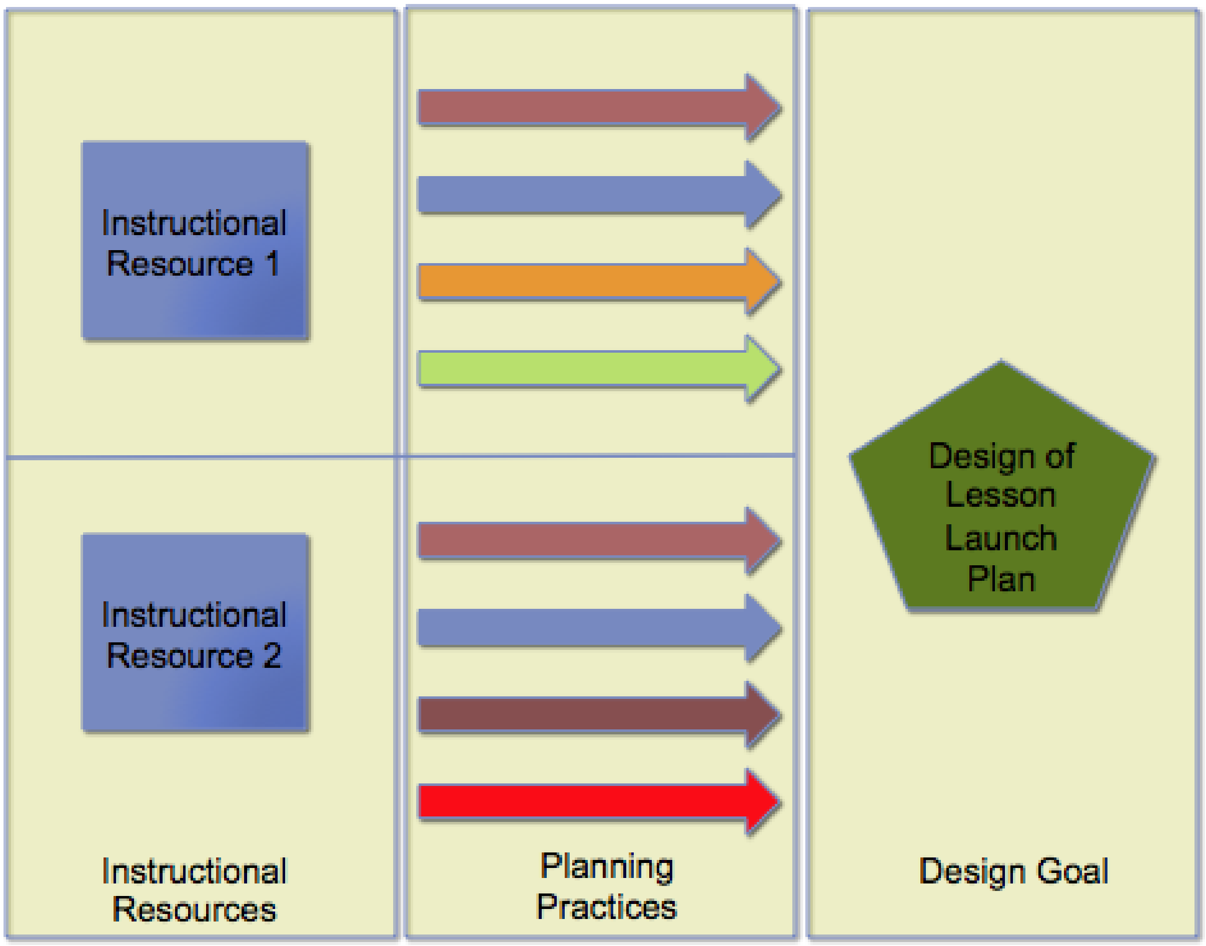


Figure 35. Instructional Resources with 4 Planning Practices

Prior to this study it was assumed that PSST would primarily focus on the planning practice that were the central focus of the pedagogy course instruction at that time instructional design was taking place (Ross, 2014). This is in part a response to aligning their ideas with the course and in part because of a limited cognitive capacity to attend all of these practices.

Data from this study show that the PSST did continue to attend to certain planning practices. However, the data also suggest that, rather than continually try and leverage all of these planning practices across the different instructional resources, the PSST began leveraging planning routines. Planning routines are sets of planning practices that are leveraged in combination to address a particular instruction goal (for example to launch a lesson). In figure 36 we see how students are able to use these routines to cut across multiple instructional resources as they design specific parts of their instruction.

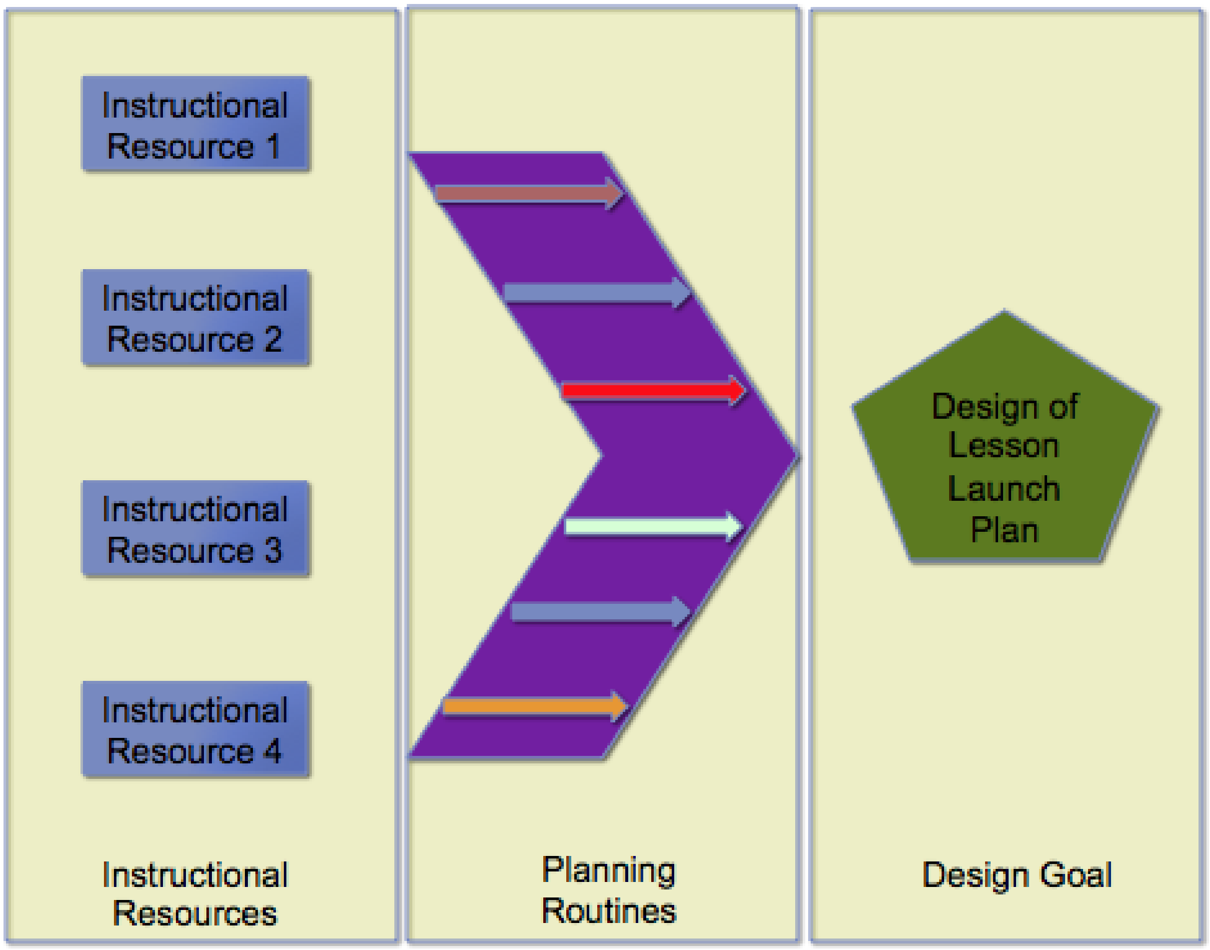


Figure 36. Example of Planning Practices Combining Into Instructional Routine

In leveraging planning routines, the PSST are still able to attend to each of the instructional resources, mostly by attending to individual planning practices that cut across multiple instructional routines without having to leverage all of the planning practices associated with every resource. In their work on classroom routines Leinhardt, Weidman, and Hammond describe routines as “fluid, paired, scripted segments of behavior that help movement toward a shared goal”. I realize the use of the term was meant to be associated with “skilled performances because the routines allow low-level actions or schemata for that actions to be performed” as described in Linehardt and Greeno 1986. Despite the terms initial meaning, I think the term translates well to the context described above. The PSST are using these routines as a way to reduce the cognitive load they experience while trying to plan, which was also a feature of classroom routines descried by Linhardt and Greeno.

To help explain this result I turn to the work of chunking (Miller, 1956). Chunking has it origins in work on memory (Miller, 1956) and problem solving (DeGroot, 1978). Central to the idea is that chunking "helps make it possible to process a great deal of information automatically" (Silver, pg. 40, 1987). Based on the example above, it is easy to see how all of these various resources and planning practices would lead to PSST chunking this information. However, it is important to point out that chunking is typically associated with expertise in a field (chess, music, math) (Gobet, 2005; Borko & Livingston, 1989). Given many of the results, especially from the interview data presented in chapter 4, I am certain that these PSST are not expert teachers. However, I contend that the PSST in this study are in the process of developing expertise, especially around lesson planning.

Given that lesson planning is a major focus of the pedagogy course sequence it seems to reason that as PSST engaged, were provided feedback, and engaged more, in the lesson planning process, they were in fact developing expertise in planning. This is supported by evidence from across the study. In the beginning of the pedagogy course sequence (through Instructional Performance 1), a majority of the PSST data demonstrate that they are leveraging individual planning practices. By the time the technology lesson plan data was collected (15 weeks into their work on planning lessons) the PSST had begun to show signs of chunking planning practices into planning routines. Now, not all planning practices made their way into the planning routines. In fact, some PSST still leveraged individual planning practices that were not linked to any routine. This could be a sign of the PSST were still developing the routines or this might be a sign that the PSST are being responsive to specific pressures related to planning. This later would be another signal that the PSST are developing expertise in their planning for engaging science instruction.

Based on the results of this study, we know that in the context of asking PSST to do complex design work, in service of supporting engaging science instruction, they seem to learn to engage with planning practices through the process of chunking them into planning routines. This development of routines over time suggest a development in PSST capacity to accomplish the design work and should be considered an important step in developing pedagogical design capacity. Ultimately if pedagogical design capacity is an indicator of expertise in teachers, this development of planning routines seems to be an important step in that trajectory.

This raises some important considerations for future work. First, what does the development of this expertise in lesson planning look like and can we track PSST trajectory. Second, what if any relationships exist between this ability to plan with routines and PSST ability to enact the instruction that is planned. Is this ability to leverage planning routines associated with or even a prerequisite for quality instruction? In the next section I discuss a number of other implications for future work that result from this study.

5.2 FUTURE WORK

The results discussed above along with the methodology used in this work point to a number of possible directions for future work. Specifically, the results around PSST work prior to pedagogy course intervention suggest a need for sampling a larger and more naturally occurring set of data related to the PSST planning. Instead of collecting only planning assignments that were situated in the pedagogy course sequence, collecting daily lessons from PSST internships may produce more robust evidence and be more conducive to statistical analysis. Specifically, I would collect more data on early planning practices and carry out nested regression analysis highlighting the relationship between planning practices and internship contextual factors.

The results of PSST work with computer simulations aver the pedagogy course intervention suggest a number of possible directions for future work. First, given the apparent gap between how PSST think about more and less authentic approximations of planning, the teacher preparation community needs to further develop supports of how to make better connections between more and less authentic work. Developing work that unpacks how PSST can be supported to transfer ideas across this authenticity of approximations is an important step forward in supporting both preservice and early in-service teachers.

Also, more work is needed to understand the possible differences between PSST, their context, and their teacher preparation program type with how they combine planning practices into routines. Do they all seem to leverage the same routines regardless of these factors? If they differ, how? What implications does this have for how we develop teacher preparation programs? Finally, what do these potential differences or similarities mean for our understanding of how PSST develop and leverage PDC for technology? This work of connecting contextual features with better preparation strategies is of particular interest to me (Rosenberg, et al., 2015). Accomplishing such work will require a much larger scale of data across multiple programs and contexts; however, I believe it could have tremendous impact on how we prepare PSST to use technology.

Next, with regard to the contextual factors studied in this work, the data relies on a set of contextual features that were self-described by the PSST. To compound the issue, most of these features were reported in their Technology Based Curricular & Site Resources assignment which was administered early on in their internship experience. This likely resulted in some resources being overlooked or misunderstood at the time. Although partially mitigated by interview data on contextual features discussed in reference to their planning, it is likely the factors and resources were overlooked resulting in a narrowed look at these factors. Ideally, the contextual features and resources would have been documented by the research for each site, however, this was not possible due to time and resource constrains.

Building on previous work which showed a lack of connection between the context and planning practices that PSST leveraged in a very similar setting (Ross, 2014), this study's results suggest that further work is necessary in order to fully understand the relationship between contextual factors and PSST planning decisions. The research field currently understands very little about the nuances of internship placement contexts and the impact this can have on PSST planning engaged science instruction supported by technology (Brown, 1990; Harris & Hofer 2009). Much more work is needed, and on a much larger scale, to truly understand the relationships between these contextual factors and PSST planning decisions with technology. This work gives a starting point by highlighting some of the important contextual features (access to computers, mentor teacher curricular use, student expectations, students ability levels) that should be considered moving forward.

Lastly, the discovery of PSST enacting planning routines raises some interesting questions for the filed. Probably of most interest to me is asking how does the use of various planning routines impact PSST delivery of instruction to secondary science students? Does leveraging routines (either with or without specific practices present) impact the instruction PSST enact? A limitation of this current work is that it focused solely on the work of teacher planning. Understanding how these planning routines are related to actual instruction is an important next step for this work and one that should help the field better understand all that goes into PSST Pedagogical Design Capacity.

5.3 CONCLUSIONS AND CONTRIBUTIONS

Technology is rapidly changing the landscape in which teachers operate. The teacher preparation program studied in this research encouraged PSST to think of themselves as instructional engineers as a way to develop the capacity to think about and use technology in support of engaged science learning. This work, in combination with the integration of technology into the pedagogy course sequence, instead of existing in its own course, makes the intervention structure responsive to past calls in the literature base for better pedagogically centered, content specific, instructionally supportive technology integration in teacher preparation (Harris et al., 2009; Hsu & Hargrave, 2000; Means & Olson, 1997; Roblyer, Edwards & Havriluk, 1997)

This dissertation adds to the research base concerned with teacher preparation education (Grossman et al., 2009; Nies, 2005; Hughes, 2007; Shoenfeld, 1998), developing and assessing preservice teachers technological pedagogical content knowledge (Mishra & Koehler, 2006; Koehler & Mishra, 2009; Schmidt et al., 2009; Harris & Hofer, 2009), and the development of teachers pedagogical design capacity (Brown, 2009; Forbes & Davis, 2010; Ross, 2014). In this work, I described how PSST attend to planning engaged science learning that leverages technology as they progressed through their teacher preparation pedagogy course sequence.

Specifically, this work conceptualizes how novice teachers combine technology and non-technology planning practices into planning routines that they then leverage in order to plan engaging instruction supported with technology.

APPENDIX A

COURSE SYLLABUS

Table 20. Jumpstart Course Syllabus

	Date	Topic	Readings for Today	Assignments Due Today
class 1	Tuesday 8/26	• Classroom Community • A Model of Engaged Science Learning (Part 1)		
class 2	Wednesday 8/27	• A Model of Engaged Science Learning (Part 2)	**Next Generation Science Standards, Appendix F** (Science & Engineering Practices) http://www.nextgenscience.org/next-generation-science-standards	
class 3	Friday 8/29	• Dr. Milner Talk Discussion • Supporting Engagement in Science Learning	5 Practices for Orchestrating Productive Task-Based Discussions in Science, Chapters 1 & 2	
class 4	Tuesday 9/2	• Nature of Science	**Ten Myths of Science: Reexamining What We Think We Know About the Nature of Science.** William McComas (1996). School Science & Mathematics, 96(1): 10-16.	**1. FOA 1** **2. NOS Essay**
class 5	Wednesday 9/3	• Introduction to Lesson Planning		**3. Lesson Plan 1**
class 6	Friday 9/5	• Curricular Ideologies	**A History of Ideas in Science Education: Implications for Practice.** George DeBoer (1991). **Curriculum Theory: Conflicting Visions and Enduring Concerns, Chapter 6**. M.S.Schiro (2012).	**4. Ideology Inventory** **5. Online Quiz – Components of instruction** **6. Lesson Plan 1 – Revised** **7. Ideology Reflection**

Table 21. Teaching & Learning 1 Course Syllabus

	Date	Topic	Readings for Today	Assignments Due Today
class 1	Wednesday 9/10	• Course Overview • Agenda • Curricular Ideologies Revisit • Task Selection & Challenging Tasks • Anatomy of a lesson • Micro-teaching practice: ***Launch***	*5 Practices for Orchestrating Productive Task-Based Discussions in Science*, **Chapter 1**	1. Revised Lesson Plan 1 2. Curricular Ideology Reflection
class 2	Wednesday 9/17	• Lesson Planning Process • Lab Launch and Safety		
class 3	Wednesday 9/24 (3:00 -7:30pm)	• ADDIE • Supporting Engagement	*Teaching Models* **Chapter 2** *(Posted on Coursweb)*	**1. LP 2**
class 4	Wednesday 10/1	• Anticipating & Getting Ready to Monitor	*5 Practices for Orchestrating Productive Task-Based Discussions in Science*, **Chapters 2 & 3**	
class 5	Wednesday 10/8 (3:00 -7:30pm)	• Monitoring, Selecting, Sequencing, and Connecting • Micro-teaching practice: ***Connect & Close***	*5 Practices for Orchestrating Productive Task-Based Discussions in Science*, **Chapters 4 & 5**	**2. Anticipating & Monitoring HW**
class 6	Wednesday 10/15	• Lesson Arcs • Micro-teaching practice: ***Monitoring*** • Learning Cycle	*5 Practices for Orchestrating Productive Task-Based Discussions in Science*, **Chapter 6**	**3. Selecting, Sequencing, and Connecting HW**

Table 21 (Continued)

class 7	Wednesday 10/22 (3:00 -7:30pm)	• Introduction to Assessment	Chapter 4: Classroom Assessment and Inquiry from NRC (2000) *(posted on Courseweb)*	**4. LP 3 (5 Practices)**
class 8	Wednesday 10/29	• Motivation & Equity	Review and bring *Deep Knowledge* by Douglas Larkin	**5. Equity Assignment**
class 9	Wednesday 11/5 (3:00 -7:30pm)	• Integrating Technology in Science Classrooms	Teaching Models, chapter 4	**6. LP 4 (tech)**
class 10	Wednesday 11/12	• Assessment Workshop: development • Co-Planning 1		
class 11	Wednesday 11/19 (3:00 -7:30pm)	• Assessment Workshop: feedback • Supporting Literacy in the Science Classroom		**7. Bring 8 hard copies of your assessment (#s 8 & 9 on workshop handout)** **8. Co-Planning 1 complete by 11/22**
class 12	Wednesday 12/3	• Integrating Technology in Science Classrooms	TBA	
class 13	Wednesday 12/10 (3:00-7:30pm)	• Co-Planning 2		**9. Co-Planning 2 complete by 12/13**

APPENDIX B

ANTICIPATING LESSON MATERIALS

Context: You are teaching 7th grade life science. It is early in the year and you want to use the Frog task to help students achieve the following goals:

Learning Goals:

1. Scientists use various mathematical processes and representational tools to notice patterns in data and to share their results with others.
2. Scientists must provide evidence to support the claims that they make.

Objectives:

1. Working in collaborative groups, students will be able to use appropriate mathematical tools (e.g. calculating mean) and representational strategies to identify and show patterns in data.
2. During the whole-class discussion, students will provide and/or request appropriate evidence to support claims.

Frog Task:

The Frog Problem in Bakersville Park

Visitors to Bakersville Park have been noticing some strange looking frogs in and around some of the ponds!

Around Baker, Charles, and Emerald ponds, they have been seeing frogs with too few or too many legs!

None of the deformed frogs have been spotted around Arlington or Dodd ponds, though.

Local scientists are wondering: ***what is causing these strange deformities***?
They have two hypotheses:

1. There is some kind of chemical pollution in Baker, Charles, and Emerald ponds that is causing the frogs to be deformed.
2. There is a disease-causing organism (a bacterium or parasite) in these ponds that is causing the deformities.

Which of the two hypotheses do you support?
What specific data support your conclusion?
Be prepared to convince your peers of your claims. *Include some representation of data in your presentation.*

APPENDIX C

MONITORING LESSON MATERIALS

In class you will engage your classmates—playing the role of 8th grade students who developed the water models contained in this packet—in a discussion.

The discussion will serve as the main instructional task during the Explain portion of a hypothetical learning cycle. By the time the **discussion** and **close** are finished, students should have achieved the Learning Goals of the lesson.

Table 22. Monitoring Lesson Learning Goals

TARGET LEARNING GOALS
LG 1: All molecules are constantly in motion.
LG 2: States of matter are characterized by different molecular motion: Solid: molecules vibrate Liquid: molecules move randomly with limits Gas: molecules move randomly with no limits
LG 3: To transform solid water into liquid water (melting), you need to add heat energy. To transform liquid water into gaseous water (boiling), you need to add heat energy. The opposite is also true: condensing gas to liquid requires a loss of heat; freezing (liquid to solid) requires a loss of heat.
LG 4: When you add heat energy to a substance, the molecules of the substance move more/faster.
LG 5: Increased molecular motion moves molecules farther apart (in almost all substances).
LG 6: Water is the only substance for which the molecules of the solid are farther apart than the molecules of the liquid. This happens because the hydrogen bonds in water are most stable in a rigid array that includes space between the molecules (to minimize the forces due to slightly like-charged particles repelling one another).

The models you and your classmates will talk about are below. Make sure to think about what the model means to you in terms of how 8th graders would think about molecular interaction given the work they would have completed around water molecules.

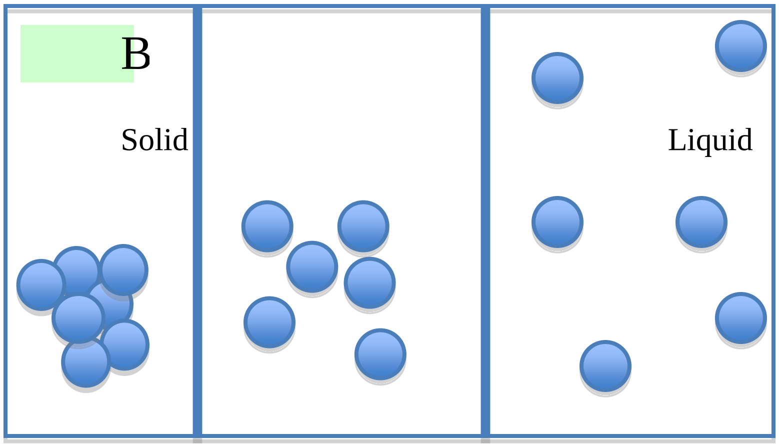


Figure 37. Monitoring Lesson Group B Example

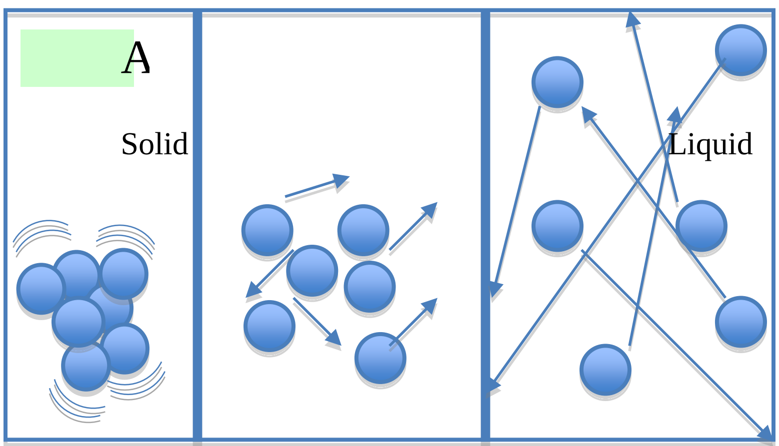


Figure 38. Monitoring Lesson Group A Example

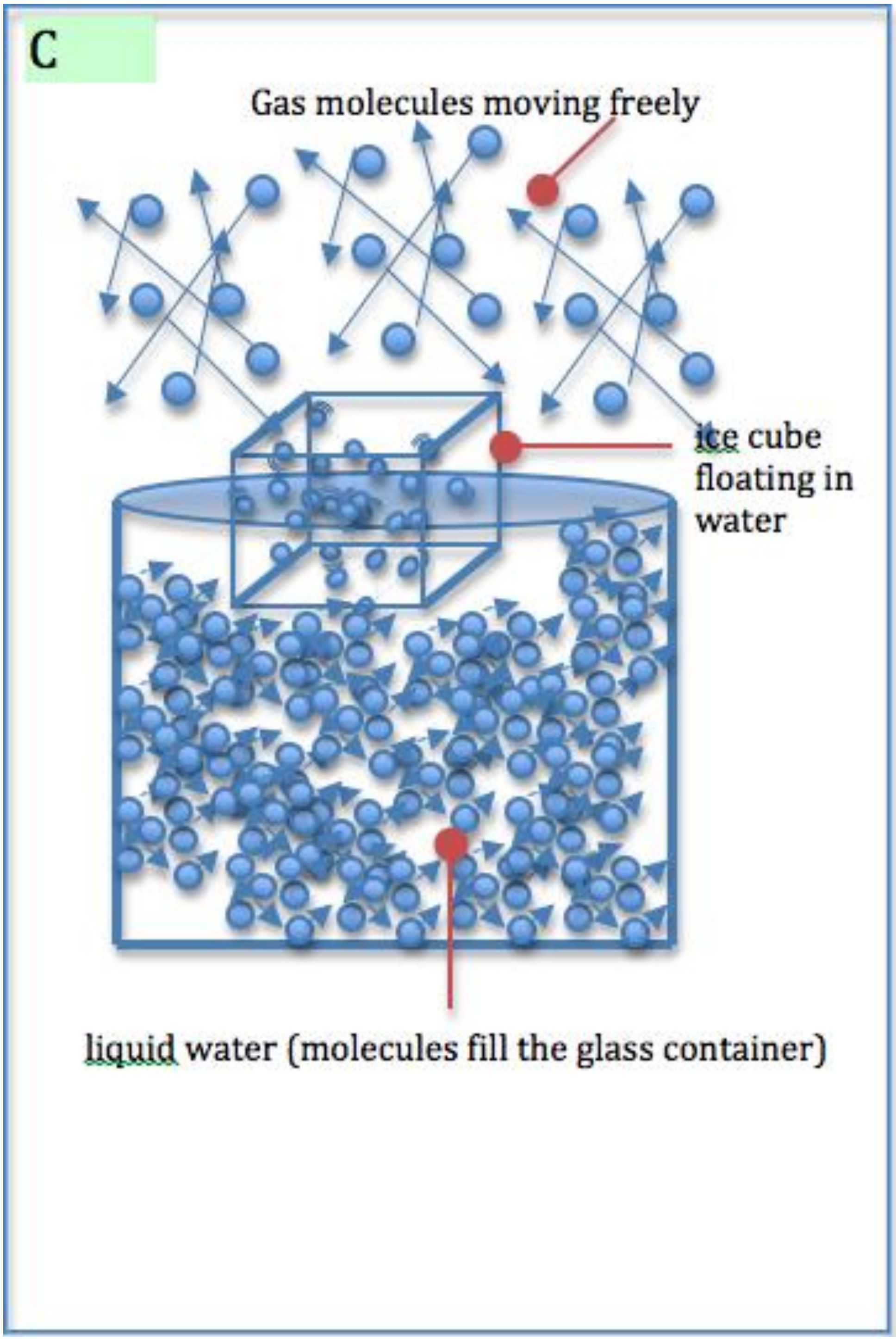


Figure 39. Monitoring Lesson Group C Example

APPENDIX D

SIMULATOR LESSON MATERIALS

Part 1 (Role-Play):

Context: You are a 11th grade academic chemistry student. It is early middle of the year and you are exploring Kinetic Molecular Theory with your classmates. In order to do so you will be using this simulator (pictured below) to collect data to answer the questions:

- What is the relationship between:
  - Pressure – Volume
  - Temperature – Volume
  - Pressure – Temperature
  - Moles – Pressure
- Collect evidence from the simulator to support your claims as we share our ideas with the class.

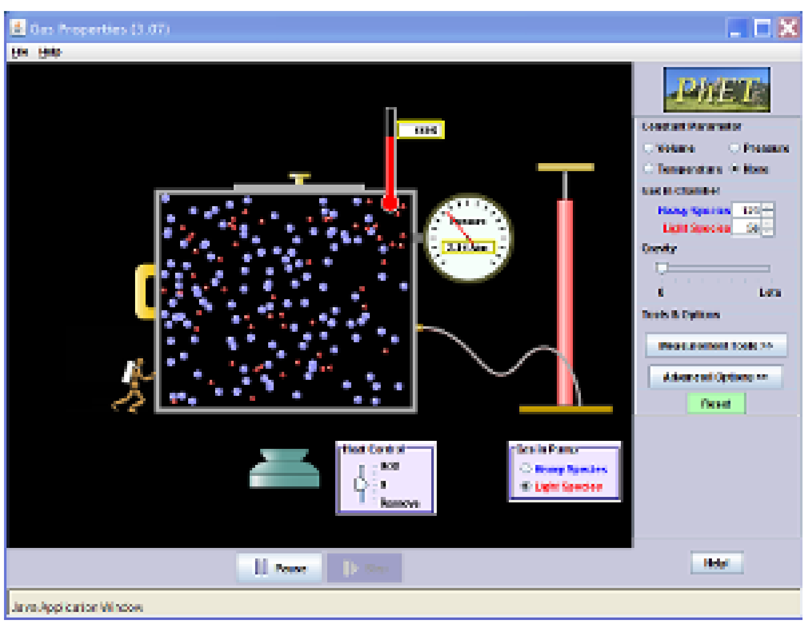


Figure 40. Gas Law Simulation Screen Capture

Part 2 (Teacher Discussion):

- What aspects of the technology allowed me to ask these questions?
- Does the technology have other parts or aspects that were not utilized in this task?
  - What other types of questions do you think you could ask using this simulation?
- What are some constraints of this technology
  - What types of questions are not appropriate to ask with this simulation?

Other simulations to look at and then revisit these questions:

- http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/flashfiles/gaslaw/boyles_law_new.html

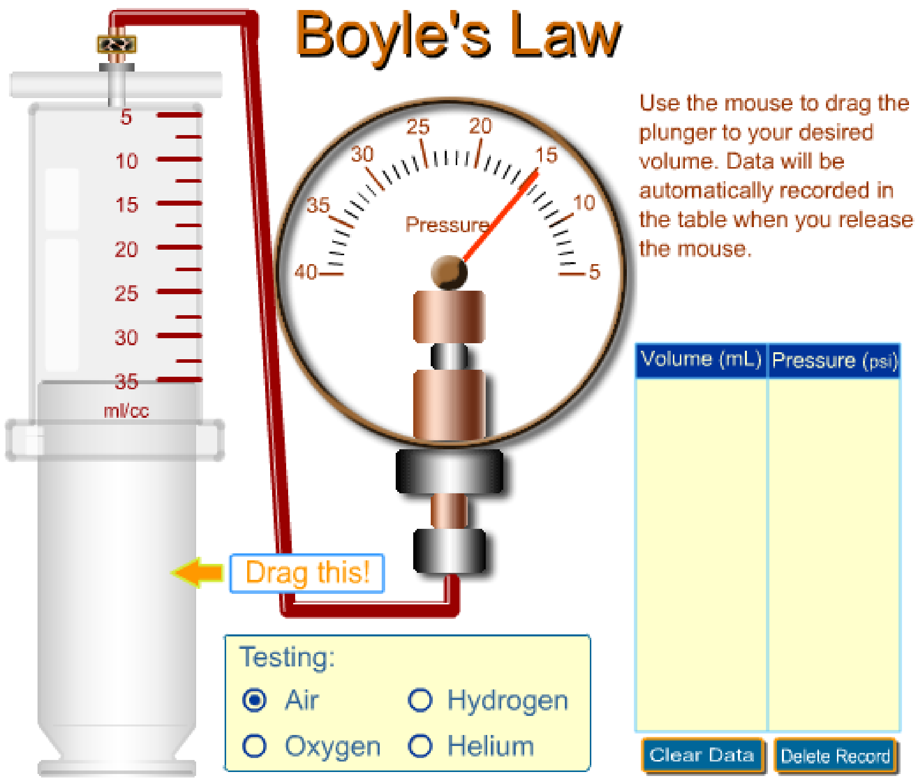


Figure 41. Boyle's Law Simulation Screen Capture

- http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/flashfiles/gaslaw/charles_law.html

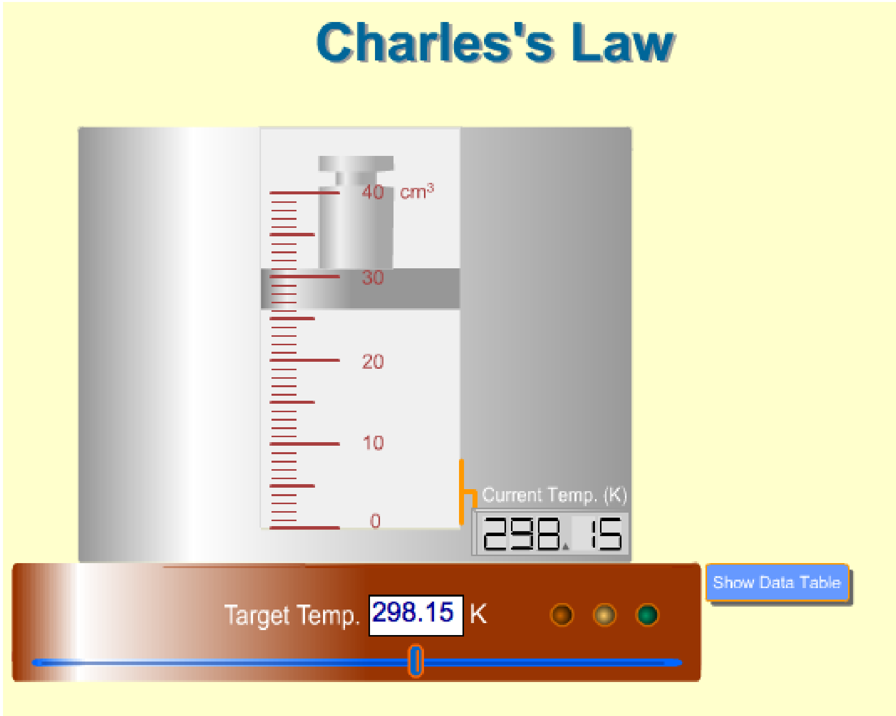


Figure 42. Charles's Law Simulation Screen Capture

APPENDIX E

TECHNOLOGY BASED CURRICULAR & SITE RESOURCES ASSIGNMENT

Technology In My Classroom

1) What are aspects of technology that you want to utilize in your classroom?

2) What technology do you have access to in your classroom and school?

3) What technological resources accompany your curriculum materials (ie, online book, electronic images, technology based models or simulations…Etc)

4) What routines do you feel are in place with students to facilitate use of technology in your classroom?

5) If you could get any technology into your placements cite what would it be and why?

APPENDIX F

SAMPLE TPACK SURVEY (BIOLOGY)

Technology Knowledge (TK)

Strongly Disagree = SD Disagree = D Neither Agree/Disagree = N Agree = A Strongly Agree = SA

1. I know how to solve my own technical problems.	SD	D	N	A	SA
2. I can learn technology easily.	SD	D	N	A	SA
3. I keep up with important new technologies.	SD	D	N	A	SA
4. I frequently play around with the technology.	SD	D	N	A	SA
5. I know about a lot of different technologies.	SD	D	N	A	SA
6. I have the technical skills I need to use technology.	SD	D	N	A	SA
7. I have had sufficient opportunities to work with different technologies.	SD	D	N	A	SA

Content Knowledge (CK)

Strongly Disagree = SD Disagree = D Neither Agree/Disagree = N Agree = A Strongly Agree = SA

Science					
8. I have sufficient knowledge about my science content area.	SD	D	N	A	SA
9. I can use a scientific way of thinking.	SD	D	N	A	SA
10. I have various ways and strategies of developing my understanding of science.	SD	D	N	A	SA
11. I continue to learn new things about my science content area.	SD	D	N	A	SA

Pedagogical Knowledge (PK)

Strongly Disagree = SD Disagree = D Neither Agree/Disagree = N Agree = A Strongly Agree = SA

12. I know how to assess student performance in a classroom.	SD	D	N	A	SA
13. I can adapt my teaching based upon what students currently understand or do not understand.	SD	D	N	A	SA
14. I can adapt my teaching style to different learners.	SD	D	N	A	SA
15. I can assess student learning in multiple ways.	SD	D	N	A	SA
16. I can use a wide range of teaching approaches in a classroom setting.	SD	D	N	A	SA
17. I am familiar with common student understandings and misconceptions.	SD	D	N	A	SA
18. I know how to organize and maintain classroom management.	SD	D	N	A	SA

Pedagogical Content Knowledge (PCK)

Strongly Disagree = SD Disagree = D Neither Agree/Disagree = N Agree = A Strongly Agree = SA

27. I can select effective teaching approaches to guide student thinking and learning around cell biology..	SD	D	N	A	SA
28. I can select effective teaching approaches to guide student thinking and learning around organisms.	SD	D	N	A	SA
29. I can select effective teaching approaches to guide student thinking and learning around genetics.	SD	D	N	A	SA
30. I can select effective teaching approaches to guide student thinking and learning around evolution.	SD	D	N	A	SA

Technological Content Knowledge (PCK)

Strongly Disagree = SD Disagree = D Neither Agree/Disagree = N Agree = A Strongly Agree = SA

31. I know about technologies that I can use for understanding and doing cell biology.	SD	D	N	A	SA
32. I know about technologies that I can use for understanding and doing organism biology.	SD	D	N	A	SA
33. I know about technologies that I can use for understanding and doing genetics.	SD	D	N	A	SA
34. I know about technologies that I can use for understanding and doing evolutionary biology.	SD	D	N	A	SA

Technological Pedagogical Knowledge (TPK)

Strongly Disagree = SD Disagree = D Neither Agree/Disagree = N Agree = A Strongly Agree = SA

35. I can choose technologies that enhance the teaching approaches for a lesson.	SD	D	N	A	SA
36. I can choose technologies that enhance students' learning for a lesson.	SD	D	N	A	SA
37. My teacher education program has caused me to think more deeply about how technology could influence the teaching approaches I use in my classroom.	SD	D	N	A	SA
38. I am thinking critically about how to use technology in my classroom.	SD	D	N	A	SA
39. I can adapt the use of the technologies that I am learning about to different teaching activities.	SD	D	N	A	SA

Technological Pedagogical Content Knowledge (TPACK)

Strongly Disagree = SD Disagree = D Neither Agree/Disagree = N Agree = A Strongly Agree = SA

40. I can teach lessons that appropriately combine cell biology, technologies, and teaching approaches.	SD	D	N	A	SA
41. I can teach lessons that appropriately combine organism biology, technologies, and teaching approaches.	SD	D	N	A	SA
42. I can teach lessons that appropriately combine genetics, technologies, and teaching approaches.	SD	D	N	A	SA
43. I can teach lessons that appropriately combine evaluation, technologies, and teaching approaches.	SD	D	N	A	SA
44. I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn.	SD	D	N	A	SA
45. I can use strategies that combine content, technologies, and teaching approaches that I learned about in my coursework in my classroom.	SD	D	N	A	SA
46. I can provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches at my school and/or district.	SD	D	N	A	SA
47. I can choose technologies that enhance the content for a lesson.	SD	D	N	A	SA

Figure 43. Sample TPACK Survey

APPENDIX G

SIMULATION SCENARIO FROM A

Technology Scenario A:
(Biology) Ant Simulation

Context: You are teaching a group of 22 tenth grade academic biology students in a 45 min period. These students vary in ability level and include 4 students with reading disabilities. Each student has access to his or her own computer with reliable Internet access.

Learning Goals:

1. Allele frequency is the number of copies of a particular allele divided by the total number of copies of all alleles in a population gene pool (the total number of genes of every individual in population).
2. Natural selection is when the better adapted (more fit) individuals survive and reproduce, passing on their genes to the following generations.
    a. If natural selection is very selective it can have a major effect on allele frequencies over several generations
3. Gene flow is the movement of alleles into or out of a population (immigration or emigration).
    a. Gene flow can introduce or reintroduce alleles into a population (increase variation) or can change allele frequencies.

Objectives:

1. After performing the ant simulation, students will be able to hypothesize how allele frequencies are altered by natural selection.

Technology Resource:
http://www.mhhe.com/biosci/genbio/virtual_labs/BL_12/BL_12.html

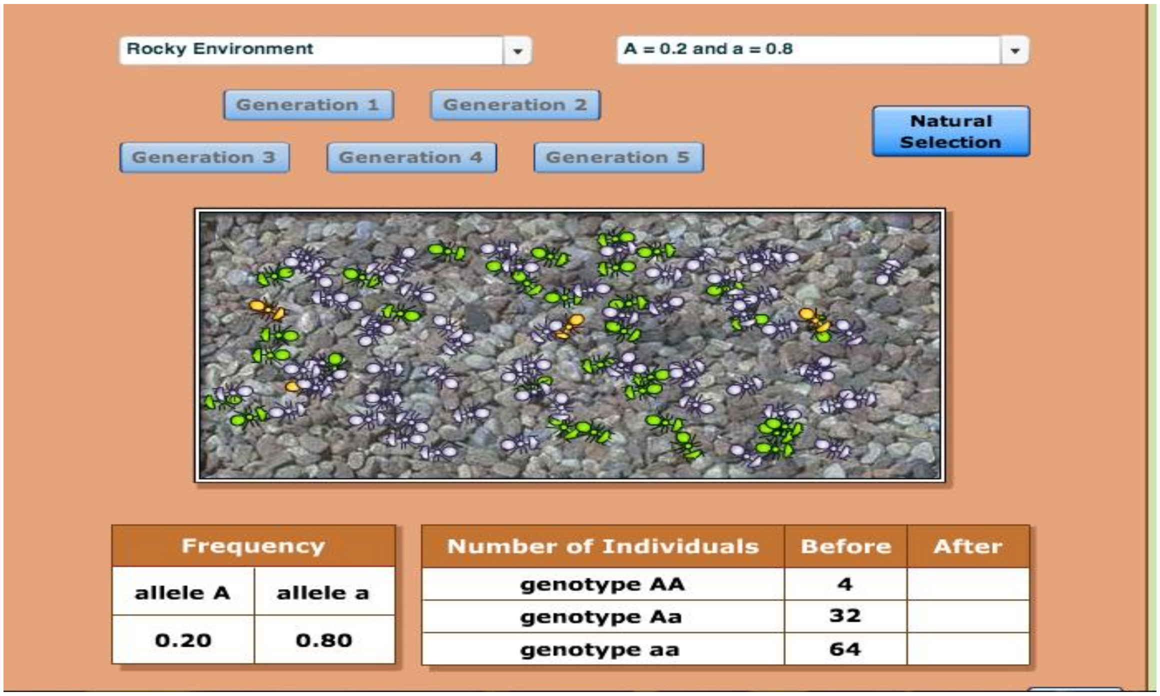


Figure 44. Ant Simulation Screen Capture

1) Given the context information provided evaluate the Affordances of this simulation to achieve the learning goal.

2) Given the context information provided evaluate the Constraints of this simulation to achieve the learning goal.

3) Assuming you are required to use this simulation by mentor teacher, explain what you will ask the students to do and why. (Remember you may use the simulation in any way you see fit)

4) What if any materials would you provide the students. You don't need to actually cerate the materials just describe what they are.

5) Describe what kinds of interactions are going to occur. These can be interactions between students, teacher and student, student and materials.

Technology Scenario A:
(Chemistry) Concentration Simulation

Context: You are teaching a group of 18 eleventh grade academic chemistry students in a 45 min period. These students vary in ability level and include 4 students with reading disabilities. Each student has access to his or her own computer with reliable Internet access.

Learning Goals:

1. Solutions are mixtures that are made up of a solute and a solvent.
2. The more solute you add to a set amount of solvent causes the solution to have a greater concentration.
3. Diluting a solvent is the result of increasing the amount of solvent in the solution and results in a decrease in concentration.
4. Evaporation of a solution causes a decrease of the solvent resulting in a higher concentration.

Objectives:

1. Students will be able to collect data and make hypothesis about what happens to concentration of a solution as the amount of solute increases.
2. Students will be able to collect data and make hypothesis about what happens to concentration of a solution as the amount of solvent increases.
3. Students will be able to collect data and make hypothesis about what happens to concentration of a solution as evaporation occurs.

Technology Resource:
https://phet.colorado.edu/sims/html/concentration/latest/concentration_en.html

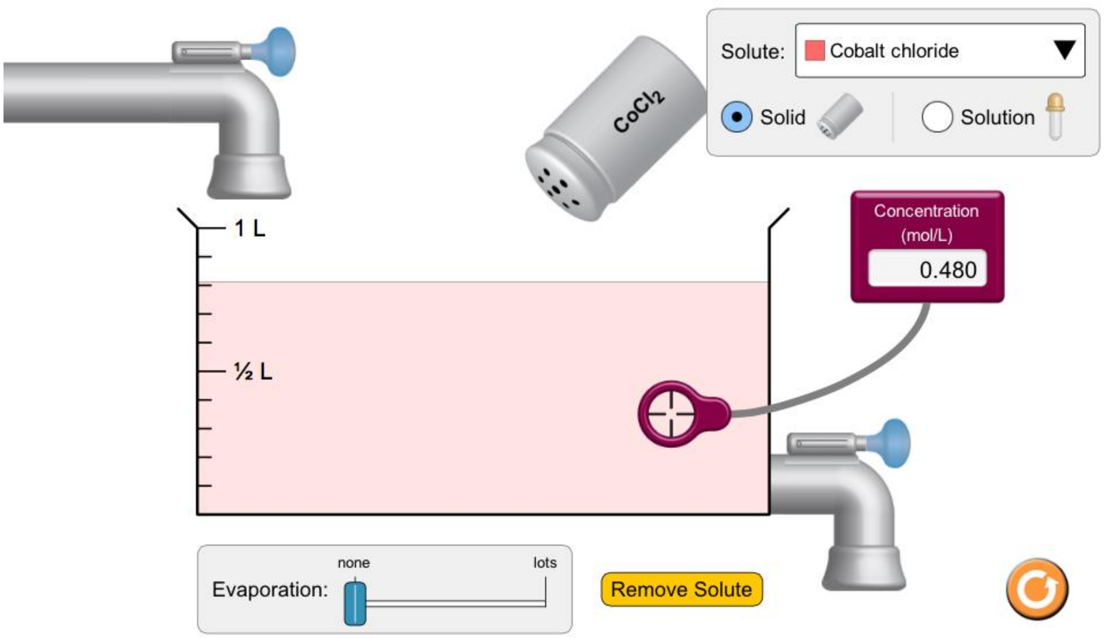


Figure 45. Chemistry Simulation Screen Capture

1) Given the context information provided evaluate the Affordances of this simulation to achieve the learning goal.

2) Given the context information provided evaluate the Constraints of this simulation to achieve the learning goal.

3) Assuming you are required to use this simulation by mentor teacher, explain what you will ask the students to do and why. (Remember you may use the simulation in any way you see fit)

4) What if any materials would you provide the students. You don't need to actually cerate the materials just describe what they are.

5) Describe what kinds of interactions are going to occur. These can be interactions between students, teacher and student, student and materials.

Technology Scenario A:
(Physics) Roller Coaster Simulation

Context: You are teaching a group of 22 twelfth grade academic chemistry students in a 45 min period. These students vary in ability level and include 4 students with reading disabilities. Each student has access to his or her own computer with reliable Internet access.

Learning Goals:

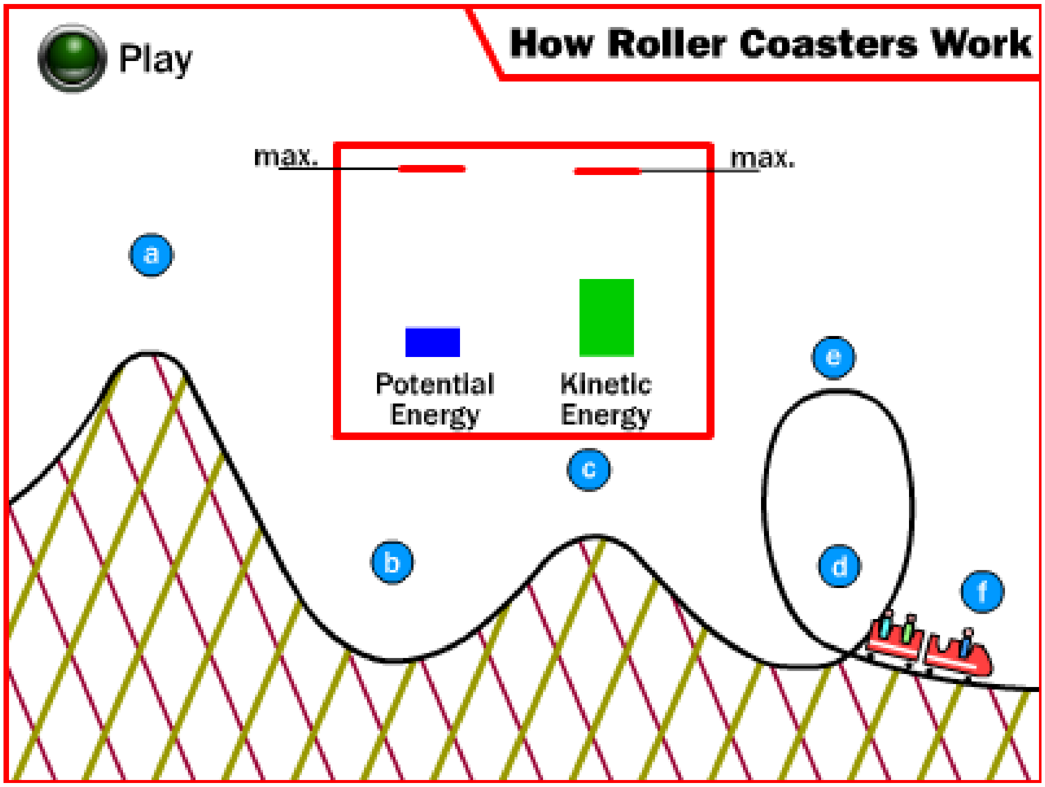
1. Kinetic energy is the energy of motion which contrasts to the stored energy of potential energy.
2. Gravitational potential energy increases with height.
3. Energy within a system is always conserved, it is neither lost nor gained only converted-in the case of the roller coaster to potential or Kinetic energy or heat.

Objectives:

1. Using the simulation students will be able to compare situations of gravitational and potential energy and determine that gravitational potential energy is greater at greater heights.
2. SWBAT identify where energy conversions occur in a roller coaster.

Technology Resource:

http://www.classzone.com/books/ml_science_share/vis_sim/mfm05_pg126_coaster/mfm05_pg126_coaster.html



© How Stuff Works

Figure 46. Physics Simulation Screen Capture

1) Given the context information provided evaluate the Affordances of this simulation to achieve the learning goal.

2) Given the context information provided evaluate the Constraints of this simulation to achieve the learning goal.

3) Assuming you are required to use this simulation by mentor teacher, explain what you will ask the students to do and why. (Remember you may use the simulation in any way you see fit)

4) What if any materials would you provide the students. You don't need to actually cerate the materials just describe what they are.

5) Describe what kinds of interactions are going to occur. These can be interactions between students, teacher and student, student and materials.

Technology Scenario A:
(General Science/Earth & Space) Earth Seasons Simulation

Context: You are teaching a group of 23 eighth grade general science students in a 45 min period. These students vary in ability level and include 4 students with reading disabilities. Each student has access to his or her own computer with reliable Internet access.

Learning Goals:

1. The closer to the equator you are, the more direct sunlight you receive. The closer to the polar regions you are, the less direct sunlight you receive
2. Average temperatures change with latitudinal location, with the equator being the warmest latitude and the Polar Regions being the coolest.
3. The tilt of the Earth's axis with respect to the sun causes the Earth's seasons and many of its weather patterns.

Objectives:

1. Working in groups, students will use the simulation to characterize the sunlight received at important lines and points of latitude in either the Northern or Sothern Hemisphere
2. Using data gathers by small groups students will derive an explanation for the intensity of sunlight at a given latitude, and will make inferences about the effects on these differences on the biosphere.

Technology Resource:
http://astro.unl.edu/naap/motion1/animations/seasons_ecliptic.html

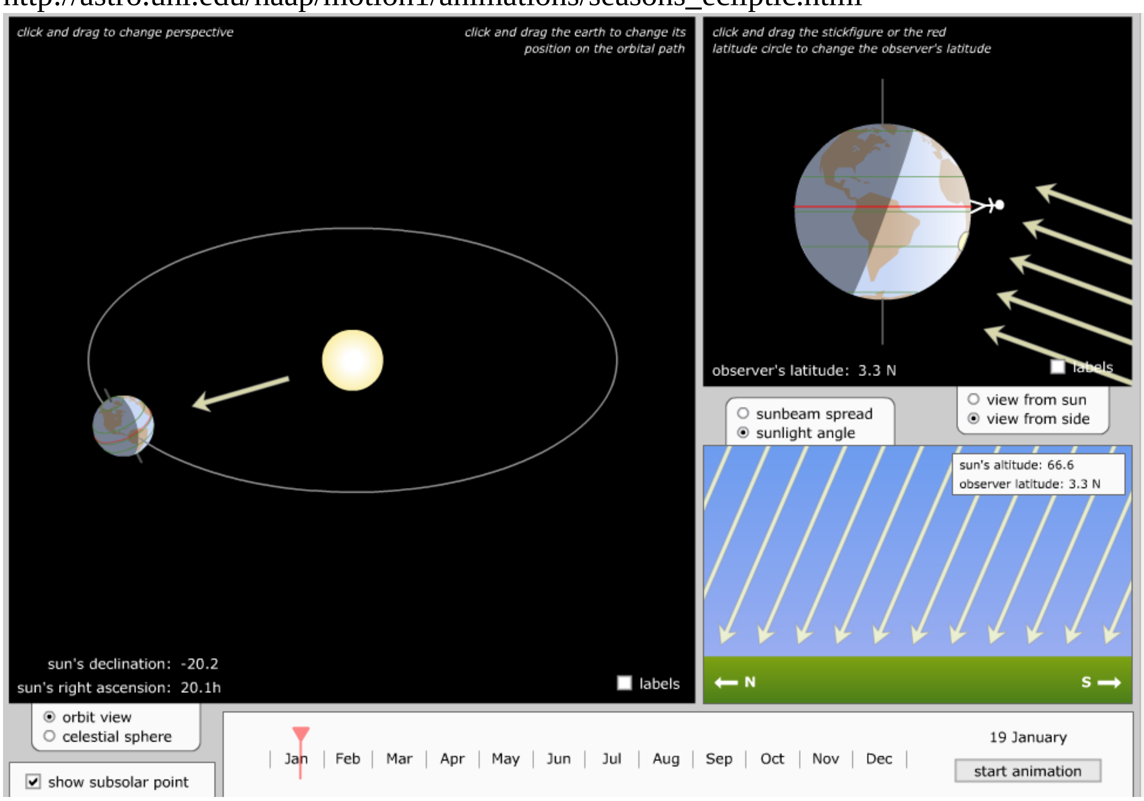


Figure 47. General Science Simulation Screen Capture

1) Given the context information provided evaluate the Affordances of this simulation to achieve the learning goal.

2) Given the context information provided evaluate the Constraints of this simulation to achieve the learning goal.

3) Assuming you are required to use this simulation by mentor teacher, explain what you will ask the students to do and why. (Remember you may use the simulation in any way you see fit)

4) What if any materials would you provide the students. You don't need to actually cerate the materials just describe what they are.

5) Describe what kinds of interactions are going to occur. These can be interactions between students, teacher and student, student and materials.

APPENDIX H

LESSON PLAN ASSIGNMENT 1

Teaching & Learning in Secondary Science 2
I&L 2431
ASSIGNMENT: Lesson Plan 1

DUE: September 4th
SUMBIT: On Blackboard under Lesson Plan 1 Assignment

Purpose

This assignment will provide you with an opportunity to write a science lesson plan. The work you do on this assignment will be utilized in our class on instructional planning.

Please keep in mind that I am not looking for or expecting any particular features in your lesson plans at this point in time. However, I am expecting your best, thoughtful work. Don't worry about whether what you chose to do is "right" or "wrong" as those labels are not meaningful in this context of this assignment. Simply do your best to fulfill the requirements of the task as they are described below.

Requirements

1. Write an instructional plan for a lesson in which your students will have an opportunity to engage in at least one scientific practice (from the Next Generation Science Standards).
2. Your lesson plan should be a minimum of 2 typed, double-spaced pages long. There is no maximum limit for the length of the plan.
3. The main task in which the students engage during the lesson should be challenging in some ways. (consider out discussion about challenging tasks for class)
4. You may use materials (tasks, plans, etc.) that you find on the internet, in curriculum materials, or have obtained from others. If you use prepared materials please be sure to –
    a. Re-type the material, adding or changing things as you see fit
    b. Provide a complete citation of the source
    c. Provide a copy of the original material
5. Set the stage for your lesson-
    a. Tell me what grade level student you are planning for (you can choose).
    b. Tell me whether you are planning for a 45-minute period or an 80-minute block.
6. Write up your lesson plan in whatever format you choose. You are free to use any lesson planning template with which you are familiar or to cerate your own. Try to include all the

information that you'd find necessary to enable you to teach the lesson. (In other words, with this lesson plan and the necessary materials for the task you've chosen, you ought to be "good to go" as the lead teacher…)

Topic Selection

Your lesson must be related to one of the topics in the list below.

General

  Making and justifying claims in science

Earth & Space Science:

  Moon phases

Biological Sciences:

  Mendelian inheritance of traits

Physical Science:

  Behavior of water at the molecular level

APPENDIX I

LESSON PLAN ASSIGNMENT 2

Teaching & Learning in Secondary Science 2
I&L 2431
ASSIGNMENT: **Lesson Plan 2**

DUE: **September 24, 2014 (9:00AM)**

SUMBIT: Lesson Plan on Blackboard under Assignments > Lesson Plan 2.

Purpose

This assignment will provide you with an opportunity to continue practicing planning lessons where the primary goal is to engage all learners in high cognitive demand tasks. It will also provide an opportunity to consider carefully the ways in which you might launch a lab to support student learning.

Requirements

1. Develop a Lesson Plan for a lesson that **involves students participating in Lab work**.

2. Your lesson plan should include all of the required information as indicated on the LESSON PLAN RUBRIC.

3. As before, you may use materials (tasks, plans, etc.) that your mentor provides or that you find on the internet, etc. If you use prepared materials please be sure to —
    a. Re-type the material as needed, adding or changing things as you see fit.
    b. Provide a complete citation for the source.
    c. Provide a copy of the original material as an attachment.
4. Submit your lesson plan in the Assignment folder of Blackboard.

APPENDIX J

LESSON PLAN ASSIGNMENT 3

Teaching & Learning in Secondary Science 2
I&L 2431
ASSIGNMENT: **Lesson Plan 3**

DUE: **November 5th**

SUMBIT: On Blackboard under Assignments > Lesson Plan 3

Purpose

This assignment will provide you with an opportunity to continue practicing planning lessons where the primary goal is to engage all learners in high cognitive demand tasks while using technology to facilitate those tasks.

Requirements

1. Your lesson plan should include all of the required information as indicated on the LESSON PLAN 3 RUBRIC (posted on Blackboard).
2. Your lesson plan should also include the following components:
    a. Select a technology that you plan to use in your class for this lesson. (ex. Lab probes, simulations, graphing program on computer, presentation tool). Make sure to describe or include links or examples of the technology.
    b. Describe what you or your students will be doing with the technology over the course of the lesson. The more specific the better.
    c. Include a justification for *why* you have selected *this technology* for *this lesson*.
3. As before, you may use materials (tasks, plans, etc.) that your mentor provides or that you find on the internet, etc. If you use prepared materials please be sure to —
    a. Re-type the material as needed, adding or changing things as you see fit.
    b. Provide a complete citation for the source.
    c. Provide a copy of the original material as an attachment.
4. Submit your lesson plan on blackboard under the assignments link > Lesson Plan 3.

APPENDIX K

INSTRUCTIONAL PERFORMANCE 1

INSTRUCTIONAL PERFORMANCE #1: LEAD A DISCUSSION
Due: 10/30/14

Please schedule the lesson (with your mentor teacher) **as soon as you can.**

- Once you have scheduled the lesson, let your field supervisor know ASAP. Field supervisors have to observe many students, so your scheduled lesson MUST fit within that overall schedule.

***IF* YOU HAVE OBTAINED PERMISSION TO VIDEOTAPE,** remember to have a video camera (you can borrow a Flip camera or use your smart phone) and permission folder available for your field supervisor on the day of your scheduled lesson.

- Keep a folder with students' permission forms in it.
- Have this folder and list available for the Field Supervisor on the day of your scheduled lesson.

The Requirements of the Teaching Task

- You facilitate a **discussion for *at least*** 25 minutes
  - The discussion must involve students drawing upon their questions, ideas, or artifacts from a high cognitive demand task and discussing *with* each other (not just you).
- You use a marking tool (whole class level, e.g. you completing a chart on the board or an individual note-taking).
  - The tool can be used consistently throughout the discussion or only at the lesson close.

Things to consider in your planning:

- Which task will you discuss and what are the student artifacts (models, assignments, data tables, and so forth) that you can draw upon in your discussion?
- How will you design the discussion so that students have opportunities to deliberate, add to, challenge, and/or question other students' ideas?
  - Which types of strategies will you use to facilitate such a discussion (consider the Lemov and Boynton & Boynton readings as well as techniques from other resources)?

Preparing to Teach

This assignment dovetails with Lesson Plan 3 from Teaching and Learning 2. Hence, you will use that lesson plan but focus on the discussion aspect of it for this assignment. You will receive feedback on Lesson Plan 3 quickly so that you have enough time to modify the lesson before teaching it for this assignment.

Your field supervisor will observe only the lesson involving the discussion but the planning for and teaching of the high cognitive demand task is just as important, as it provide the student work/artifacts you will use in the discussion for this observation and assignment.

On The Day That You Teach

1. Arrive at your school early and make sure everything is ready to go. It is best if you prepare materials (slides, handouts, etc.) the day before at the latest.

2. Have a hard copy of your lesson plan ready to hand to your Field Supervisor when s/he arrives to view your lesson.

3. Also provide your Field Supervisor with the folder with video permission records (if applicable).

4. Finally, provide the Field Supervisor with the video camera or smart phone if you are going to record the lesson.

5. Set aside some time in your schedule for a post-lesson conference with your Field Supervisor.

Reflecting on Teaching

Answer these questions (typed) drawing on any evidence you have from the lesson, including your own observations, feedback from your mentor teacher and/or field supervisor, and written artifacts produced by the students.

1) Did students achieve the desired Learning Goals? To answer this question, draw from specific evidence (things students said and/or produced, such as an exit slip). Include reference to relevant student work within your response (i.e. direct quotes from students), but include the digital copy of the source (aka student work) labeled appropriately in an appendix.

2) Comment on the Launch portion of your lesson. Did students understand the purpose of the discussion? Did they understand what they were expected to do during the discussion (that is, how you wanted them to participate)? Provide specific evidence to support your claim. (Again, include the copies in the appendix, labeled appropriately so I know it is for this question.)

3a) Consider the students' engagement during the lesson by addressing each of the following:

- Did students seem able to engage in the discussion (according to the rules/expectations you provided)?
- What did engagement look like in relation to your expectations?
- Which aspects of participating in the discussion seemed to challenge your students the most?
- Which aspects of the discussion were easiest for them?

3b) How can you help the students get better at engaging in this type of discussion?

4a) What elements of the high cognitive demand task (that they completed prior to the discussion) were most productive in terms of eliciting productive thinking and responses from the students? What elements of the task were problematic?

4b) Would you change the task if you were to do this again? If so, in what ways?

5a) How comfortable were you leading the discussion? Did you feel nervous or relaxed?

5b) To what extent do you feel you succeeded at leading the discussion (promoting students' engagement) and not stepping in and "telling?" Provide specific examples of where you felt you succeeded and where you have room for improvement.

6) Describe the role that **planning** played in your ability to conduct this lesson. Make sure to discuss

- the role of anticipating students' work,
- developing tools to elicit thinking,
- establishing norms for participating, and
- the changes you made to your lesson based on the feedback on Lesson Plan 3.

7) Describe at least 3 concrete "take away" lessons you have learned about how to lead a student-centered discussion. In particular, talk about what you would do again (related to preparing for or implementing a discussion) or what you would avoid doing. Provide a rationale for your choices.

Documenting Practice

You will submit **Instructional Performance 1 Assignment** to Courseweb by October 30th. The assignment includes:

(1) Revised Lesson Plan 3

(2) Instructional Materials

Include copies of all materials you used during the discussion lesson. This includes copies of the representations (such as data tables) you/students used, any handouts or slides, etc. If you use materials obtained from other sources (internet, your mentor), please be sure you cite the source clearly in the footer of the document.

(3) Feedback from your field supervisor

(4) Reflection Questions

(5) Appendix of Student Work

Include copies of the work that students produced during the high cognitive demand task (the artifacts that you used to anchor your discussion) as well as the scanned/digitized evidence you use to support your reflection questions.

APPENDIX L

INSTRUCTIONAL PERFORMANCE 2

INSTRUCTIONAL PERFORMANCE #2: SIMULATION TECHNOLOGY LESSON

Due: 11/25/14

Please schedule the lesson (with your mentor teacher) **as soon as you can.**

- Once you have scheduled the lesson, let your field supervisor know ASAP. Field supervisors have to observe many students, so your scheduled lesson MUST fit within that overall schedule.

IF **YOU HAVE OBTAINED PERMISSION TO VIDEOTAPE,** remember to have a video camera (you can borrow a Flip camera or use your smart phone) and permission folder available for your field supervisor on the day of your scheduled lesson.

- Keep a folder with students' permission forms in it.
- Have this folder and list available for the Field Supervisor on the day of your scheduled lesson.

The Requirements of the Teaching Task

Students engaging with a digital simulation in a way that promotes learning that would not otherwise be possible without the use of the simulation. Make sure that you have thought through, while you are planning, what the simulation and your class are capable of accomplishing in relation to the your Learning Goals. This engagement should occur either through or in service of a high cognitive demand task.

For example,

- Students are able to collect data from a reaction simulation on the number of compounds that exist at various points in an equilibrium reaction allowing them to create reaction graphs. (NOTE: Just collecting the data by itself is not a high demand task. Having the students think about how it can be represented and shared in a graph does make it high demand.)

Things to consider in your planning:

- How will you use the simulation to develop a high cognitive demand task for all your students?
- How will you help your students learn the science using the simulation (rather than focusing only on the use of the simulator)?

- What is a simulation you feel comfortable teaching with and can be adept at using during this lesson?
- Can your mentor and/or supervisor provide you with helpful suggestions?

Preparing to Teach

Write a Lesson Plan.

- Your Lesson Plan should address all of the requirements described in the standard rubric (IP2 rubric).
- Your lesson must have a Launch, Task, Student Simulation Engagement (For this section you should include the written out version of some of the questions and thinking I have asked you to do above) and Close.
- Include sufficient detail to enable you to support the simulation engagement, similarly to the way you planned for the 5P discussion. (i.e. You should anticipate how students will interact with the technology and how you plan to monitor and mediate those interactions to ensure that students will accomplish the desired LGs.)

Discuss your lesson plan with your mentor teacher and/or field supervisor and make any revisions as per his/her suggestions. It is also a VERY GOOD IDEA to get feedback on the high cognitive demand task and the lesson in which you intend to complete this work.

On The Day That You Teach

6. Arrive at your school early and make sure everything is ready to go, including the simulation. It is best if you prepare materials (slides, handouts, etc.) the day before at the latest.

7. Have a hard copy of your lesson plan ready to hand to your Field Supervisor when s/he arrives to view your lesson.

8. Also provide your Field Supervisor with the folder with video permission records (if applicable).

9. Finally, provide the Field Supervisor with the video camera or smart phone if you are going to record the lesson.

10. Set aside some time in your schedule for a post-lesson conference with your Field Supervisor.

Reflecting on Teaching

Answer these questions (typed) drawing on any evidence you have from the lesson, including your own observations, feedback from your mentor teacher and/or field supervisor, and artifacts produced by the students.

1) Did students achieve the desired learning goals? To answer this question, draw from specific evidence (things students said and/or produced, such as an exit slip), incorporating direct quotes from student work. Put copies of relevant student work in a separate file labeled Appendix of Student Work.

2) Comment on the Launch portion of your lesson. Did students understand what they were expected to do while working with the simulation (that is, how you wanted them to participate)? Provide specific evidence to support your claim.

3) Did students seem able to engage with the simulation (according to the rules/expectations you provided)? What aspects of engaging with simulation seemed to challenge your students the most?

4) How can you help the students get better at engaging with simulations like the one you selected?

5) How comfortable were you engaging your students with the simulation? Did you feel nervous or relaxed? What do you think were the major factors that contributed to these feelings?

6) To what extent do you feel you succeeded at engaging students with simulation? Provide specific examples of where you felt you did a good job and where you would have done something differently if you could go back and do it again.

7) Describe the role that **planning** played in your ability to conduct this lesson.

8) Describe at least 3 concrete "take away" lessons you have learned about engaging students with simulations. In particular, talk about what you would definitely do again (related to preparing for or implementing technology) or what you would definitely avoid doing. Provide a rationale for your choices.

Documenting Practice

You will submit the **Instructional Performance 2 Assignment** to Coursewb by November 25th.

Your Packet should include the following (<u>in order</u>, with <u>labeled tabs</u> to assist in finding things):

(1) Lesson Plan

(2) Instructional Materials

Include copies of all materials you used during the lesson. This includes copies of the representations you used, any handouts or slides, etc. If you use materials obtained from other sources (internet, your mentor), please be sure you cite the source clearly in the footer of the document.

(3) Feedback from your field supervisor

(4) Reflection questions

(5) Appendix of student work

Include copies of the work that students produced during the high cognitive demand task (the artifacts that you used to anchor your discussion) as well as the scanned/digitized evidence you use to support your reflection questions.

APPENDIX M

INSTRUCTIONAL PERFORMANCE 3

INSTRUCTIONAL PERFORMANCE #3: STUDENT TECHNOLOGY LESSON

Due: 12/15/14

Please schedule the lesson (with your mentor teacher) **as soon as you can.**

- Once you have scheduled the lesson, let your field supervisor know ASAP. Field supervisors have to observe many students, so your scheduled lesson MUST fit within that overall schedule.

IF **YOU HAVE OBTAINED PERMISSION TO VIDEOTAPE,** remember to have a video camera (you can borrow a Flip camera or use your smart phone) and permission folder available for your field supervisor on the day of your scheduled lesson.

- Keep a folder with students' permission forms in it.
- Have this folder and list available for the Field Supervisor on the day of your scheduled lesson.

The Requirements of the Teaching Task

Design a lesson in which students engage with technology in a way that promotes learning that would not otherwise be possible without the use of the technology. Make sure that you have thought through, while you are planning, what the technology and your class are capable of accomplishing in relation to your learning goals. This technology use should occur either through or in service of a high cognitive demand task.

For example,

- Students create visual representations with data using Excel and make precise extrapolation of trends in the data. (NOTE: Just having them plot data might be difficult from a skill-with-the-technology standpoint but it is not *cognitively demanding* in relation to the science learning we want them to accomplish.)

- Students are able to collect data from a reaction simulation on the number of compounds that exist at various points in an equilibrium reaction allowing them to create reaction graphs. (NOTE: Just collecting the data by itself is not a high demand task. Having the students think about how it can be represented and shared in a graph does make it high demand.)

- Students use motion sensors in order to test the relationship between different velocities of different massed objects dropped from the same height. (NOTE: Again, exploring the relationship and supporting claims with evidence collected is what makes this high demand. Just collecting the data is a relatively simple, and low demand, technology task.)

Students engaging with technology should:

- Be active participants with the technology.
- Be able to see, experience, or create something that would not otherwise be possible.
- Be thinking about and making connections to scientific ideas.
- Be aware of your expectations for their engagement with the technology and the product of those interactions.

Preparing to Teach

Work with your mentor teacher to identify a topic / lesson where you can incorporate technology.

Obtain copies of any materials related to this lesson (including the task).

You will need to prepare in advance ways to get the students to engage with the technology. You should be thinking hard about how to support students' use of the technology in service of demanding learning tasks.

a) Consider the possible ways in which the students will engage with the technology and prepare ways to redirect or draw attention to the technology while maintaining high demand in relation to the science learning. (Often feedback during class focuses on how to use the technology rather than focusing on the science the students should be learning.)

b) Use strategies such as tossing and revoicing (teacher revoicing as well as student revoicing) to support engagement with the technology.

Write a lesson plan.

- Your lesson plan should address all of the requirements described in the IP3 rubric.
    - Your lesson must have a Launch, Task, Student Technology Engagement and Close.
- Include sufficient detail to enable you to support the technology engagement, similarly to the way you planned for the 5P discussion. (i.e. You should anticipate how students will interact with the technology and how you plan to monitor and mediate those interactions to ensure that students will accomplish the desired LGs.)

Discuss your lesson plan with your mentor teacher and/or field supervisor and make any revisions as per his/her suggestions. It is also a VERY GOOD IDEA to get feedback on the high cognitive demand task and the lesson in which you intend to complete this work.

TEST your technology several days ahead of time.

For example,

- Make sure the simulator you want the students to use works on the student login computers.

- Make sure your school firewall does not block the video you want to have students view.

- Be familiar with the various intricacies of smart boards or clicker interfaces you plan on using.

Your field supervisor will observe this lesson and provide you with feedback for this assignment.

On The Day That You Teach

11. Arrive at your school early and make sure everything is ready to go, including the technology. It is best if you prepare materials (slides, handouts, etc.) the day before at the latest.

12. Provide your field supervisor with

    a. A hard copy of lesson plan,
    b. Video permission records, if applicable, and
    c. The video camera or smart phone for recording (if applicable).

13. Set aside some time in your schedule for a post-lesson conference with your field supervisor.

Reflecting on Teaching

Answer these questions (typed) drawing on any evidence you have from the lesson, including your own observations, feedback from your mentor teacher and/or field supervisor, and artifacts produced by the students.

1) Did students achieve the desired learning goals? To answer this question, use specific evidence (things students said and/or produced, such as an exit slip), incorporating direct quotes from student work. Put copies of relevant student work in a separate file labeled Appendix of Student Work.

2) Comment on the Launch portion of your lesson. Did students understand what they were expected to do while working with the technology (that is, how you wanted them to participate)? Provide specific evidence to support your claim.

3) Did students seem able to engage with the technology (according to the rules/expectations you provided)? Provide evidence. What aspects of engaging with technology seemed to challenge your students the most? Providence evidence.

4) How can you help the students get better at engaging with technologies like the one you selected?

5) How comfortable were you engaging your students with the technology? Did you feel nervous or relaxed? What do you think were the major factors that contributed to these feelings?

6) To what extent do you feel you succeeded at engaging students with technology? Provide specific examples of where you felt you did a good job and where you would have done something differently if you could go back and do it again.

7) Describe the role that **planning** played in your ability to conduct this lesson.

8) Describe at least 3 concrete "take away" lessons you have learned about engaging students with technology. In particular, talk about what you would definitely do again (related to preparing for or implementing technology) or what you would definitely avoid doing. Provide a rationale for your choices.

Documenting Practice

You will submit **Instructional Performance 3 Assignment** to Courseweb by December 15th. The assignment includes:

(1) Lesson plan

(2) Instructional materials

Include copies of all materials you used during the lesson. This includes copies of the representations you used, any handouts or slides, etc. If you use materials obtained from other sources (internet, your mentor), please be sure you cite the source clearly in the footer of the document.

(3) Feedback from your field supervisor

(4) Reflection questions

(5) Appendix of student work

Include copies of the work that students produced during the high cognitive demand task (the artifacts that you used to anchor your discussion) as well as the scanned/digitized evidence you use to support your reflection questions.

APPENDIX N

INTERVIEW PROTOCOL

I will begin interview by reminding the PST that whatever we talk about will not impact their grade or coursework.

I will ask the PST how they are doing and if they are having any problems at their placements. This will hopefully give some insight if they are having difficulties that could impact the planning process.

Referencing the lesson plan or IP that is the focus of this interview I will ask a series of questions about the planning work they have submitted:

1) Can you briefly tell me where in the unit this lesson fell and where in a learning cycle it was located (if it was in one)?
2) Tell me about the lesson you chose for these learning goals
    a. Where did you get this idea from?
3) Can you tell me the ideas or things you focused on when you were doing this planning? (depending on how they respond)
    a. What about students thinking
        i. Prior Knowledge?
        ii. Sequence of lessons?
        iii. Ability level?
    b. What about school resources?
    c. What about your abilities to facilitate this lesson?
4) What aspects of the planning process did you find most difficult?
    a. Why do you think this was so hard for you?
5) Please explain to me the level of demand you think this tasks requires your students to engage in and why?
    a. What is the underlying scientific ideas they are thinking about?
    b. How have you planned to maintain or support that demand during the lesson?
    c.
6) Tell me about the simulation/technology you selected?

7) Did you consider using any other simulations/technology for this lesson?
8) When you selected the simulation/technology what were some of the deciding factors for its selection? (Depending on response may prompt for specific responses around.)
    a. Students
    b. Availability
    c. Relation to LG
    d. Part of curriculum or mentor's work
9) What do you consider to be the Affordances of this simulation/technology?
    a. Why is this an affordance?
    b. How have you used these affordances in your planning or decision-making process?
    c. How does this relate to any of your other instructional decisions in your plan?
10) What do you consider to be some Constraints of this simulation/technology?
    a. Why is this a Constraint?
    b. How does this relate to any of your other instructional decisions in your plan?
    c. How do you overcome these constraints?
11) Have you taught this lesson?
    a. How do you think it went
    b. Would you change anything about the lesson
        i. Why?
    c. What did you like about your planning?
        i. What parts of your planning helped with the lesson?
    d. Did the technology do serve the purpose you had hoped it would?
        i. Any evidence from class to support this?

APPENDIX O

LESSON PLAN RUBRIC

Table 23. Lesson Plan Rubric

Lesson Section	Section Code	Code Level/description				
		N/A	Not Mentioned	Inadequate	Adequate	Fully Developed
Launch	Connection to previous work	x	Plan has no mention of previous work	Launch plan mentions that lesson will be connected to previous work but does not say how	Launch Plan includes how the lesson will be connected to previous work but no detail beyond that	Launch Plan includes details of how to connect lesson to previous work and gives reasons for this connection
	Motivates student participation	x	Launch Plan has no mention of motivating students to participate	Launch Plan has mention of motivating student but no explanation of how.	Launch Plan explains how they will try and motivate students with no explanation of why they selected this method	Launch Plan explains how they will try and motivate students with explanation of why
	Communicates the purpose of task	x	Launch Plan has no mention of the purpose of task	Launch Plan has mention of purpose but no explanation of what it is.	Launch plan explains the purpose of the task	Launch Plan explains the purpose of the task and how this is connected to other ideas
	Communicates the expectations of the task	x	Launch Plan has no mention of student expectations	Launch Plan has mention of student expectations but no details of what they are.	Launch Plan has explains student expectations **but not how they** will be addressed.	Launch Plan has explained **student expectations and how they will be addressed.**

Table 23 (Continued)

<table>
<tr><td rowspan="6">Tasks</td><td colspan="2" rowspan="2">Initial Level of CD</td><td>Task not Described</td><td>Low</td><td>High</td></tr>
<tr><td></td><td>Initial task as described is of low cognitive demand and requires little or no connections to underlying scientific idea</td><td>Initial task as described is of high cognitive demand and has clear connections to underlying scientific idea</td></tr>
<tr><td rowspan="2">SEP Use</td><td colspan="2">No</td><td colspan="2">Yes</td></tr>
<tr><td colspan="2">Lesson plan shows that PSST is not engaging the students in any of the science and engineering practices from the NGSS</td><td colspan="2">Lesson plan shows that PSST is engaging the students in at least one of the science and engineering practices from the NGSS</td></tr>
<tr><td rowspan="2">Offload work to curriculum material</td><td colspan="2">Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="2">Lesson plan suggests that PSST is offloading instructional work to the curricular materials or the technology. Does not support students in tasks as that is role of technology</td><td colspan="2">Lesson plan shows PSST does not offload, fully supports students interactions with the technology or CM in service of learning goals.</td></tr>
</table>

Table 23 (Continued)

		N/A	Not Mentioned	Inadequate	Adequate	Fully Developed
5P/general Work time	Supporting Task: Anticipating	x		Mentions anticipating student thinking but does not describe	**Partially describe**s anticipation of student thinking and the work necessary to support students' engagement with the task	**Completely describes** anticipation of student thinking and the work necessary to support students' engagement with the task
	Supporting Task: Questions	x		Talk about asking students questions but does not give specifics about it.	**Partially describes** the plan for asking students questions/ supporting talk among students/ how you will engage students in discussion around the lesson task	**Completely describe**s the plan for asking students questions/ supporting talk among students/ how you will engage students in discussion around the lesson task
	Supporting Task: Materials	x		The quality of the written materials (instructions, slides, data tables, etc.) **is low**	The quality of the written materials (instructions, slides, data tables, etc.) **is good**	The quality of the written materials (instructions, slides, data tables, etc.) **is high**
	Supporting Task: LG Connection	x		Makes reference between the task and learning goal but **does not provide support**	Makes some reference between tasks and Learning Goals **with support or evidence**	**Makes clear connections** to between the task and supporting the Learning Goal(s)

Table 23 (Continued)

		N/A	Not Mentioned	Inadequate	Adequate
Technology Work Time	Engagement with Technology	Non Technology Lessons		**Talks about** the need to support students engagement with the technology but provides no specifics	**Partially describes** how students will engage with the technology in support of the given task giving specific examples.
	Management of student work with technology	Non Technology Lessons		**Talks about** how PSST will support students work with the technology without giving specific examples	**Partially describes** how PSST will support students work with the technology with specific examples
	Maintaining Demand	Non Technology Lessons		**Talks about the need for** PSST to toss demand back to students rather than take over the work	**Partially describes** how PSST will toss demand back to students rather than take over the work
		Yes		No	
	Offload work to technology	Lesson plan suggests that PST is offloading instructional work to the technology. Does not support students in tasks as that is role of technology		Lesson plan shows PST does not offload, fully supports students interactions with the technology in service of learning goals.	

Table 23 (Continued)

		N/A	Not Mentioned	Inadequate	Adequate	Fully Developed
Technology Resource	Description of Affordances	Non Technology Lessons		Describes the affordances **but does not make clear connections to tasks or student work**	Makes clear connections between the affordances of the technology and how it supports the task **or** student work	Makes clear connections between the affordances of the technology and how it supports the task **and** student work
	Description of constraints	Non Technology Lessons		Describes the constraints **but does not make clear connections to tasks or student work**	Makes clear connections between the constraints of the technology and how it supports the task **or** student work	Makes clear connections between the constraints of the technology and how it supports the task **and** student work

Table 23 (Continued)

		No Sign	Minimal Knowledge	Some Knowledge	Adequate Knowledge	Strong Knowledge
TPACK	PCK		PSST makes some reference between technology and resources selected with minimal parts of the instructional moves that support the different LGs and or content	PSST makes a specific connection between technology and resources selected with some of the parts of the instructional moves that support the different LGs and or content	PSST makes a specific connection between technology and resources selected with many of the parts of the instructional moves that support the different LGs and or content	PSST makes a specific connection between technology and resources selected with the parts of the instructional moves that support the different LGs and or content
	TCK		PSST make some reference between instructional moves and resources selected with the technology that supports the content	PSST makes a specific connection between instructional moves and resources selected with some of the parts of the technology that supports the content	PSST makes a specific connection between instructional moves and resources selected with many of the parts of the technology that supports the content	PSST makes clear connection between instructional moves and resources selected with the parts of the technology that supports the content

Table 23 (Continued)

TCK		PSST make some reference between instructional moves and resources selected with the technology that supports the content	PSST makes a specific connection between instructional moves and resources selected with some of the parts of the technology that supports the content	PSST makes a specific connection between instructional moves and resources selected with many of the parts of the technology that supports the content	PSST makes clear connection between instructional moves and resources selected with the parts of the technology that supports the content
TPK		PSST makes some connection between the tasks and resources selected with the parts of the technology and instructional moves	PSST makes a specific connection between the tasks and resources selected with some of the parts of the technology and instructional moves	PSST makes a specific connection between the tasks and resources selected with many of the parts of the technology and instructional moves	PSST makes clear connection between the tasks and resources selected with the parts of the technology and instructional moves

Table 23 (Continued)

		N/A	Not Mentioned	Inadequate	Adequate	Fully Developed
Close	Connects to main lesson ideas	x	Plan has no mention of main ideas of the lesson	mentions that lesson will be connected to main ideas but does not say how	includes how the lesson will be connected to main ideas (does not have to make connection explicit) but no detail beyond that	includes details of how to connect lesson to main ideas and gives reasons for this connection
	Connections to future work	x	Plan has no mention of future work	mentions that lesson will be connected to future work but does not say how	includes how the lesson will be connected to future work but no detail beyond that	includes details of how to connect lesson to future work and gives reasons for this connection
	Communicates requirements (HW, assignments, next steps)	x	Plan has no mention of requirements moving forward	mentions that students will have an assignment or work to complete but does what those requirements are	Includes the requirements that students are expected to complete as part of the lesson	Includes the requirements that students are expected to complete as part of the lesson and how this connects to next steps

APPENDIX P

SIMULATION SCENARIO RUBRIC

Table 24. Simulation Scenario Rubric

		No Sign	Minimal Knowledge	Some Knowledge	Adequate Knowledge	Strong Knowledge
Question 1	PCK		PSST makes some reference to affordances based on LG or Content	PSST makes a specific connection between affordances and at least one LG and or content	PSST makes a specific connection between affordances and most of the LG and or content	PSST makes a specific connection between affordances referencing how it supports the different LGs and or content
	TCK		PSST makes some reference to affordances based on the technology pieces and the content	PSST makes a specific connection between affordances and parts of the technologies ability to support the content	PSST makes specific connection between affordances and some of the parts of the technology that supports the content	PSST makes clear connection between affordances and the parts of the technology that supports the content
	TPK		PSST makes some reference to affordances based on the technology pieces and the instructional moves	PSST makes a specific connection between affordances and parts of the technologies in connection with instructional moves	PSST makes specific connection between affordances and some of the parts of the technology and instructional moves	PSST makes clear connection between affordances and the parts of the technology and instructional moves

Table 24 (Continued)

TPACK		PSST makes some reference connection between affordances referencing specific parts of the technology, the LG and instructional moves	PSST makes a specific connection between affordances referencing specific parts of the technology and one of the LG and instructional moves	PSST makes a specific connection between affordances referencing specific parts of the technology and most of the LG and instructional moves	PSST makes specific connection between affordances referencing specific parts of the technology and the LGs and instructional moves

		No Sign	Minimal Knowledge	Some Knowledge	Adequate Knowledge	Strong Knowledge
Question 2	PCK		PSST makes some reference to constraints based on LG or Content	PSST makes a specific connection between constraints and at least one LG and or content	PSST makes a specific connection between constraints and most of the LG and or content	PSST makes a specific connection between constraints referencing how it supports the different LGs and or content
	TCK		PSST makes some reference to constraints based on the technology pieces and the content	PSST makes a specific connection between constraints and parts of the technologies ability to support the content	PSST makes specific connection between constraints and some of the parts of the technology that supports the content	PSST makes clear connection between constraints and the parts of the technology that supports the content

Table 24 (Continued)

TPK		PSST makes some reference to constraints based on the technology pieces and the instructional moves	PSST makes a specific connection between constraints and parts of the technologies in connection with instructional moves	PSST makes specific connection between constraints and some of the parts of the technology and instructional moves	PSST makes clear connection between constraints and the parts of the technology and instructional moves
TPACK		PSST makes some reference connection between constraints referencing specific parts of the technology, the LG and instructional moves	PSST makes a specific connection between constraints referencing specific parts of the technology and one of the LG and instructional moves	PSST makes a specific connection between constraints referencing specific parts of the technology and most of the LG and instructional moves	PSST makes specific connection between constraints referencing specific parts of the technology and the LGs and instructional moves

Table 24 (Continued)

		No Sign	Minimal Knowledge	Some Knowledge	Adequate Knowledge	Strong Knowledge
Question 3	PCK		PSST mentions that the tasks plays some role in how students the engage with the content given this instructional strategy	PSST implies/mentions that the tasks gives students the opportunity to engage with the content given this instructional strategy	PSST makes a connections between how the tasks gives students the best opportunity to engage with the content given this instructional strategy	PSST makes a specific connection between how the tasks gives students the best opportunity to engage with the content given this instructional strategy
	TCK		Mentions that task has an impact on students use of the technology in order to understand the content	PSST makes any connection between how the tasks gives students the best opportunity to engage with the technology **or** content	PSST makes a any connection between how the tasks gives students the best opportunity to engage with the technology **and** content	PSST makes a specific connection between how the tasks gives students the best opportunity to engage with the technology and content
	TPK		PSST makes some reference to task(s) being influenced by the technology pieces and the instructional moves	PSST makes a specific connection between the task(s) and parts of the technologies in connection with instructional moves	PSST makes specific connection between the task(s) and some of the parts of the technology and instructional moves	PSST makes a specific connection between how the task(s) gives students the best opportunity to engage with the technology given this instructional strategy

Table 24 (Continued)

TPACK		PSST makes some reference connecting the task(s) and specific parts of the technology, the LG and instructional moves	PSST makes a specific connection between task(s) and specific parts of the technology and one of the LG and instructional moves	PSST makes a specific connection between task(s) and specific parts of the technology and most of the LG and instructional moves	PSST makes specific connection between the task(s) and specific parts of the technology and the LGs and instructional moves
Question 4	No Sign	Minimal Knowledge	Some Knowledge	Adequate Knowledge	Strong Knowledge
		Give overview of materials	Describes materials in some detail	Describes materials in detail making connections to why materials will be useful	Describes materials in detail making connections to how the materials support the science learning

Table 24 (Continued)

		No Sign		Strong Knowledge
Question 5	PCK			Description shows interactions that take into account pedagogy and content
	TCK			Description shows interactions that take into account technology and content
	TPK			Description shows interactions that take into account pedagogy and technology
	TPACK			Description shows interactions that take into account pedagogy, technology, and content

	Yes	No
Offload work to curriculum material	Answers across questions suggests that PSST is offloading instructional work to the technology. Does not support students in tasks as that is role of technology	Answers across questions shows PSST does not offload, fully supports students interactions with the technology in service of learning goals.

BIBLIOGRAPHY

Abbitt, J. T. (2011). Measuring technological pedagogical content knowledge in preservice teacher education: A review of current methods and instruments. *Journal of Research on Technology in Education*, *43*(4), 281-300.

Achieve Inc. (2014). *Development Process.* Retrieved from http://www.nextgenscience.org/development-process

Adams, W. K., Paulson, A., Wieman, C. E., Henderson, C., Sabella, M., & Hsu, L. (2008, October). What levels of guidance promote engaged exploration with interactive simulations?. In *AIP Conference Proceedings* (Vol. 1064, No. 1, p. 59).

Alonzo, A. C., & Gotwals, A. W. (2012). *Learning progressions in science: Current challenges and future directions*. Springer Science & Business Media.

American Association for the Advancement of Science. (1993). AAAS-Benchmarks. *Benchmark for Science Literacy*.

Ball, D.L., & Cohen, D.K. (1996). Reform by the book: What is –or might be – the role of curriculum materials in teacher learning and instructional reform? *Educational Reseracher*, 25(9), 6-8, 14.

Bell, R. L., & Smetana, L. K. (2008). Using computer simulations to enhance science teaching and learning. *National Science Teachers Association*, 23-32.

Blackboard Inc. | Reimagine Education | Education Technology & Services. (2015). Retrieved March 18, 2015, from http://www.blackboard.com

Borko, H., & Livingston, C. (1989). Cognition and improvisation: Differences in mathematics instruction by expert and novice teachers. *American educational research journal*, *26*(4), 473-498.

Sardo-Brown, D. (1990). Experienced teachers' planning practices: A US survey. *Journal of education for teaching*, *16*(1), 57-71.

Brown, M. (2009).The Teacher-Tool Relationship: Theorizing the Design and Use of Curriculum Materials. In Remillard, J., Herbel-Eisenmann, B., & Lloyd, G. (Ed.), Mathematics Teachers at Work: Connecting Curriculum Materials and Classroom Instruction (pp. 17-35). New York, NY: Routledge, Taylor and Francis.

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? (RS-03). Evanston, IL: The Center for Learning Technologies in Urban Schools.

Carlsen, W.S. (1987). Why do you ask? The effects of science teachers subject-matter knowledge on teacher questionsing and classroom discourse. Paper presented at the Annual Meeting of the American Educational Association.

Carlsen, W.S. (1991). Effects of new biology teachers' subject-matter knowledge on curricular planning. *Science Education. 75(6), 631-647.*

Cartier, J. L., Smith, M. S., Stein, M. K., & Ross, D. K. (2013). *5 Practices for Orchestrating Productive Science Discussions*. Reston, VA: National Council of Teachers of Mathematics and Corwin Press.

Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2010). Facilitating Preservice Teachers' Development of Technological, Pedagogical, and Content Knowledge (TPACK). *Educational Technology & Society*, *13*(4), 63-73.

Choppin, J. (2011). Learned adaptations: Teachers' understanding and use of curriculum resources. *Journal of Mathematics Teacher Education*, *14*(5), 331-353.

Collins, A., & Halverson, R. (2009). *Rethinking education in the age of technology: The digital revolution and schooling in America*. Teachers College Press

Common Core State Standards Initiative. (2010). Common Core State Standards for Mathematics. Washington, DC: National Governors Association Center for Best Practices and the Council of Chief State School Officers.

Common Core State Standards Initiative. (2010). Common core state standards for English language arts &lLiteracy in history/social studies, science, and technical subjects. *Washington, DC: Nationai Governors Association Center for Best Practices and the Council of Chief State School Officers*.

Cuban, L. (1992). Curriculum stability and change. In P.W.Jackson (Ed.), Handbook of research on curriculum. A project of the American Educational Research Association (pp. 216-247). New Your, NY: Macmillan.

Davis, E.A. & Krajcik, J. (2005). Designing educative curriculum materials to promote teacher learning. Educational Researcher, 34(3), 3-14.

Davis, E. A., Beyer, C., Forbes, C. T., & Stevens, S. (2007). Promoting pedagogical design capacity through teachers' narratives. In *annual meeting of the National Association for Research in Science Teaching, New Orleans, LA.*

DeBoer, G.E. (1991). *A history of ideas in science education: Implications for practice.* New York: Teachers College Press.

de Jong, T. (2010). Cognitive load theory, educational research, and instructional design: some food for thought. *Instructional Science*, *38*(2), 105-134.

Dilger, D. (2014, June 9). Apple's 200 student WWDC attendees 'super excited' about the future of tech. Retrieved February 17, 2015, from http://appleinsider.com/articles/14/06/09/apples-200-student-wwdc-attendees-super-excited-about-the-future-of-tech

DiSessa, A. A. (2001). *Changing minds: Computers, learning, and literacy*. Mit Press, Cambridge, MA.

Doyle, W. & Carter, K. (1984). Academic Tasks in Classrooms. *Curriculum Inquiry, 14, 129-149.*

Duschl, R., Maeng, S., & Sezen, A. (2011). Learning progressions and teaching sequences: A review and analysis. *Studies in Science Education*, *47*(2), 123-182.

Forbes, C. T., (2013). Curriculum-dependent and curriculum-independent factors in pre-service elementary teachers' adaptation of science curriculum materials for inquiry-based science. Journal of Science Teacher Education, 24, 179-197.

Forbes, C. T., & Davis, E. A. (2010). Curriculum design for inquiry: Preservice elementary teachers' mobilization and adaptation of science curriculum materials. *Journal of Research in Science Teaching*, *47*(7), 820-839.

Gobet, F. (2005). Chunking models of expertise: Implications for education. *Applied Cognitive Psychology*, *19*(2), 183-204.

Goethals, M. S., Howard, R. A., & Sanders, M. M. (2004). *Student teaching: a process approach to reflective practice: a guide for preservice and inservice teachers*. Pearson/Merrill/Prentice Hall.

Grossman, P., Compton, C., Igra, D., Ronfeldt, M., Shahan, E., & Williamson, P.W. (2009). Teaching practice: A cross-professional perspective. *Teachers College Record*, *111*, 2055-2100.

Harris, J., & Hofer, M. (2009, March). Instructional planning activity types as vehicles for curriculum-based TPACK development. In *Society for Information Technology & Teacher Education International Conference* (Vol. 2009, No. 1, pp. 4087-4095).

Harris, J. B., & Hofer, M. J. (2011). Technological pedagogical content knowledge (TPACK) in action: A descriptive study of secondary teachers' curriculum-based, technology-related instructional planning. *Journal of Research on Technology in Education*, *43*(3), 211-229.

Harris, J., Mishra, P., & Koehler, M. (2009). Teachers' technological pedagogical content knowledge and learning activity types: Curriculum-based technology integration reframed. *Journal of Research on Technology in Education*, *41*(4), 393-416.

Hiebert, J., & Stigler, J. (2000). A proposal for improving classroom teaching: Lessons from the timss video study. Elementary School Journal,, 101, 3–20.

Hsu, Y. S., & Hargrave, C. P. (2000). Survey of instructional technology courses for preservice teachers. *Journal of Technology and Teacher Education*, *8*(4), 303-314.

Hughes, E. K. (2007). Lesson Planning as a Vehicle for Developing Preservice Secondary Teachers' Capacity to Focus on Students' Mathematical Thinking (Doctoral dissertation, University of Pittsburgh).

Kessler, A. M. & Cartier, J. (2014). Science teacher pedagogical design capacity with technology in an integrated teacher preparation program. Poster presented at 11th International Conference of the Learning Sciences, Boulder, CO, June 2014

Koehler, M.J., & Mishra, P. (2008). Introducing tpck. AACTE Committee on Innovation and Technology (Ed.), *The handbook of technological pedagogical content knowledge (tpck) for educators* (pp. 3-29). Mahwah, NJ: Lawrence Erlbaum Associates.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education*, *9*(1), 60-70.

Lawson, A. E. (1989). A theory of instruction: Using the learning cycle to teach science concepts and thinking skills. The National Association for Research in Science Teaching.

Lawson, A. E. (2001). Using the learning cycle to teach biology concepts and reasoning patterns. *Journal of Biological Education*, *35*(4), 165-169.

Leinhardt, G., & Greeno, J. G. (1986). The cognitive skill of teaching. *Journal of educational psychology*, *78*(2), 75.

Leinhardt, G., Weidman, C., & Hammond, K. M. (1987). Introduction and integration of classroom routines by expert teachers. *Curriculum Inquiry*, *17*(2), 135-176.

Linn, M. C., & Hsi, S. (2000). *Computers, teachers, peers: Science learning partners*. Lawrence Erlbaum Associates, Mahwah, NJ.

Marek, E. A., Cavallo, A. M. L., & Renner, J. W. (1997). *The learning cycle: Elementary school science and beyond*. Portsmouth, NH: Heinemann.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.

Mishra & Koehler (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017-1054.

National Center for Education Statistics, U.S. Department of Education, Fast Response Survey System (FRSS), *Internet Access in U.S. Public Schools and Classrooms: 1994-2005* and *Educational Technology in U.S. Public Schools: Fall 2008*; and unpublished tabulations. (Table was prepared August 2010.)

National Center for Education Statistics, U.S. Department of Education, Common Core of Data (CCD), *State Nonfiscal Survey of Public Elementary/Secondary Education, 1990-91 through 2011-2012*. (Table was prepared December 2013.)

National Education Association. (1893). *Report on the committee on secondary school studies.* Washington, DC: U.S. Government Printing Office.

National Research Council. 2012. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, By State*s.Washington, DC: The National Academies Press.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, *21*(5), 509-523.

O'Donnell, C. L. (2008). Defining, conceptualizing, and measuring fidelity of implementation and its relationship to outcomes in K–12 curriculum intervention research. *Review of Educational Research*, *78*(1), 33-84.

Paas, F., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. *Educational psychologist*, *38*(1), 1-4.

Park, S., Jang, J. Y., Chen, Y. C., & Jung, J. (2011). Is pedagogical content knowledge (PCK) necessary for reformed science teaching?: Evidence from an empirical study. *Research in Science Education*, *41*(2), 245-260.

Pennsylvania Department of Education. (2008). Classrooms for the Future *Handbook 2008-2009*. Retrieved March 21, 2012. From http://www.portal.state.pa.us/portal/server.pt/community/classrooms_for_the_future/8911/models%2C_research___reports/536125

Pennsylvania Department of Education. (2014). Level I and Level II Evaluation Forms. Retrieved June10, 2014. From http://www.education.state.pa.us/portal/server.pt/community/applications_for_certification/8649/level_i_to_level_ii_evaluation_forms/506765

Perkins, A., Scott, T. (2014). A STEM preservice teacher preparation program: Where scientific and technological literacy meet. National Association for Research in Science Teaching 2014 Annual Meeting, Pittsburgh, PA, March 2014

Podolefsky, N. S., Perkins, K. K., & Adams, W. K. (2010). Factors promoting engaged exploration with computer simulations. *Physical Review Special Topics-Physics Education Research*, *6*(2), 020117.

Remillard, J. T. (2000). Can curriculum materials support teachers' learning? Two fourth-grade teachers' use of a new mathematics text. Elementary School Journal, 100(4), 331-350.

Remillard, J. T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. Review of Educational Research, 75(2), 211-246.

Richey, R. C., Silber, K. H., & Ely, D. P. (2008). Reflections on the 2008 AECT Definitions of the Field. *TechTrends*, *52*(1), 24-25.

Rosenberg, J., Ervin, L., Kessler, A., Harris, J., Greenhow, C., & Tai, D. (2015). How should educational technology researchers consider context? An interactive discussion on context and teaching and learning with technology. Panel presented at Society for Information Technology and Teacher Education International Conference, Las Vegas, NV, March 2015.

Ross, D. K. (2014). Examining pre-service science teachers' developing pedagogical design capacity for planning and supporting task-based classroom discussions.

Ross, D., Kessler, A., & Cartier, J. (2014). Supporting Pre-Service Science Teachers' Planning of Task Based Classroom Discussions. 11th International Conference of the Learning Sciences, Boulder, CO, June 2014

Sawyer, R. K. (Ed.). (2006). *The Cambridge handbook of the learning sciences* (Vol. 2, No. 5). Cambridge: Cambridge University Press.

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK): The development and validation of an assessment instrument for preservice teachers. *Journal of Research on Computing in Education*, *42*(2), 123.

Schiro, M. S. (2012). *Curriculum theory: Conflicting visions and enduring concerns*. Sage.

Schoology. (2015). Schoology Retrieved March 18, 2015, from http://www.schoology.com/home

Schweingruber, H., Keller, T., & Quinn, H. (Eds.). (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. National Academies Press.

Sherin, M.G. & Drake, C. (2009). Curriculum strategy framework: investigating patterns in teachers' use of a reform-based elementary mathematics curriculum. *Journal of Curriculum Studies*, 41(4), 467-500.

Shoenfeld, A. (1998). Toward a theory of teaching-in-context. *Issues in Education*, 4(1), 1-95.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4–14.

Silver, E. A. (1987). Foundations of cognitive theory and research for mathematics problem solving instruction. In Schoenfeld, A. H. (Ed.). (1987). *Cognitive science and mathematics education*. Psychology Press.

Smetana, L. K., & Bell, R. L. (2012). Computer simulations to support science instruction and learning: A critical review of the literature. *International Journal of Science Education*, *34*(9), 1337-1370.

Smith, M. S., & Stein, M. K. (2011). Five practices for orchestrating productive mathematics discussions. *Reston, VA: National Council of Teachers of Mathematics*.

Stein M. K., Grover B. W., Henningsen M. (1996). Building student capacity for mathematical thinking and reasoning: An analysis of mathematical tasks used in reform classrooms. *American Educational Research Journal*, 33(2), 455–488.

Stein, M.K., Smith, M.S., Henningsen, M.A., & Silver, E.A. (2000) *Implementing Standards-Based Mathematics Instruction: A Casebook for Professional Development*. New Your, NY; Teachers College Press, Columbia University.

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and instruction*, *4*(4), 295-312.

Valencia, S., Place, N., Martin, S., & Grossman, P. (2006). Curriculum materials for elementary reading: Shackles and scaffolds for four beginning teachers. *The Elementary School Journal*, 107(1), 93-120.

Warschauer, M. (2006). *Laptops and Literacy: Learning in the wireless classroom*. New York: Teachers College Press.

Windschitl, M., & Andre, T. (1998). Using computer simulations to enhance conceptual change: The roles of constructivist instruction and student epistemological beliefs. *Journal of research in science teaching*, *35*(2), 145-160.

Wittrock, M.C. (Ed.). (1986). *Handbook of research on teaching* (3rd ed.). New York: Macmillan.

Yin, R. K. (2002). Case Study Research: Design and Methods, (Applied Social Research Methods, Vol. 5).