INCORPORATING SCIENCE AND ENGINEERING PRACTICES INTO PRESERVICE SECONDARY SCIENCE TEACHERS' PLANNING PRACTICES: TESTING THE EFFICACY OF AN INTERVENTION

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The New Standards Framework (NRC, 2012) explicitly calls for teachers to engage students in science and engineering practices (SEPs) as they develop knowledge of scientific phenomena and canonical disciplinary ideas. This study analyzed six pre-service secondary science teachers' (PSSSTs') incorporation of SEPs into their planning practices before, during, and after an instructional intervention. The intervention, which was nested into an instructional methods course, supported the PSSSTs by representing the practices they were to engage their own students with. The PSSSTs were then able to decompose and approximate those scientific practices in their lesson planning, thereby developing pedagogical design capacity (PDC). The PSSSTs were interviewed to determine what affordances and constraints they felt when planning for incorporating SEPs into their lesson planning.

Analysis of the lesson plans showed that 50% of the PSSSTs incorporated SEPs into their lesson plans when only provided a written description of the SEPs and prompted to do so. During the instructional intervention, 83% of the PSSSTs incorporated SEPs into their lesson plans. After the instructional intervention, the PSSSTs were no longer required to incorporate SEPs into their lesson planning nor were they required to hand in lesson plans for a grade. Instead, they wrote lesson plans for their cooperating teachers and for their own use. Surprisingly, the PSSSTs not only continued to incorporate SEPs into their lessons, but did so more completely by incorporating a diversity of sub-SEPs and more of them in their lessons. This is significant because this may indicate that the instructional intervention has longevity.

Interview data suggests that PSSSTs experience both internal and external affordances and constrains when attempting to incorporate SEPs into their lesson planning. Three categories of issues (epistemic, logistical, and curricular) emerged in the results and influence how teachers interact with the SEPs as they plan lessons. This study reiterates the need for teacher educators to engage in instruction that represents aspects of scientific practice, allows for its decomposition, and engages pre-service teachers in approximating those practices.

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I dedicate this posthumously to Dr. Samuel Mitrovich, my teacher, mentor, and friend, whose passion for learning, especially science, will be with me forever.

1.0 INTRODUCTION

Engaging students in scientific practices is a core goal of contemporary reform movements in science education (AAAS, 1993; NRC, 1996; NRC 2000). The recent initiative by the National Research Council (2012) entitled *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*[1] is the most explicit yet concerning what practices should be incorporated into the existing science curriculum. In addition to advocating that students engage in scientific practices such as *developing and using models*, *analyzing and interpreting data*, and *constructing explanations*, the Framework (now referred to as the NGSS) describes how students' skills, with regard to these practices, should develop and become more sophisticated over the course of the K-12 learning trajectory.

The call to include science practices, and not just science content, in the curriculum has roots in the 19th century. The 1892 Committee of Ten, a group of reformers working with the National Education Association (NEA), urged teachers to engage students in both the hands-on and intellectually engaging work of science and to abandon dependence on textbooks and didactic instruction.

[1] The New Standards Framework has since been adopted as the key framework for the Next Generation Science Standards (NGSS), which is actively managed by Achieve (a nonprofit education reform organization).

The Committee of Ten Report (NEA, 1894) argued that the prevailing pedagogy in secondary science at the time ignored the study of nature and was therefore "highly objectionable." The report advocated that learners have direct contact of natural phenomena. Twenty two years later, Dewey (1916), implored teachers to engage students in the process of inquiry instead of purveying "already-made" facts. Schwab (1962) echoed this sentiment, advocating for students to see the uncertainty that remains in science as scientists do, and railed against teaching science as a series of truth statements.

Despite these historic proclamations, incorporation of scientific practices into classrooms remains a contemporary issue. *The Benchmarks for Science Literacy* (AAAS, 1993) and *Science for all Americans* (NRC, 1990) avoided advocating a particular method of teaching, but stressed what students should be able to do, and how students should come to know science. In 1996, the *National Science Education Standards* (NRC) pushed for authentically engaging in science content through inquiry. A more explicit guide to teaching inquiry, entitled, *Inquiry and the National Secondary Science Standards* (NRC, 2000), centered on enacting the essential features of classroom inquiry and included variations of inquiry. Five years later, *America's Laboratory Report* (NRC, 2005) presented a critical account of the work that students engage in during laboratory exercises, stating that it was "poor" for most students and did not follow the instructional design principles researched to be effective.

Research may now need to shift from focusing on the content of reform to why implementing that reform is so difficult. One reason for the difficulty may be that teachers tend to teach as they were taught. Ericsson, K. A., Krampe, R. T., and Tesch-Romer, C. (1993) report that developing expertise may require over a decade of deliberate practice. Students from a school system that lacked sufficient emphasis on practices like the SEPs may be at a deficit when they are asked to implement SEPs as pre-service secondary science teachers (PSSSTs). In fact, they may have developed practices that are antithetical to the New Standards Framework. Without first-hand experiences as learners in these reform-based contexts, teachers revert back to the didactic models that permeate traditional schooling. Abd-El-Khalick and BouJaoude (1997) make this argument, stating that teacher preparation programs are not helping teachers' develop their knowledge base for teaching about science. Additionally, teachers' thinking of teaching is dominated by tasks and activities rather than on conceptual structures and scientific reasoning (Duschl & Gitmore, 1997).

Teachers may also not fully understand what scientific practices include or have models of what those might look like in the context of K-12 classrooms. Even high quality educative curriculum materials (materials that are to help the teacher as well as the students learn) may be insufficient for promoting teacher learning about new techniques because these types of curriculum materials are not the norm and may not perturb the teachers epistemological views sufficiently to cause systemic change (Davis and Krajcik, 2005; Tsai, 2003).

Training teachers to teach differently, including instruction that engages students in what the NGSS calls *science and engineering practices* (SEPs), requires perturbing teachers' epistemological understanding of what science is and what scientists do. Windschitl, Thompson, and Braaten (2008a) call this difficult process, "re-engineering" teachers' conceptions. This engineering perspective (mentioned above) is useful for this study because the ultimate reasons for why teachers resist adopting reform based pedagogy are complex and are difficult to distill to pure "scientific reasoning." Engineers often take an instrumentalist approach, where outcomes are valued over the reasons for it. This study will borrow from the professional practice literature as a means to leverage change in PSSSTs' ability to mobilize resources to craft instructional contexts, known as pedagogical design capacity (PDC) (see Brown, 2009), for incorporating SEPs into lesson planning (see Figure 1.1).

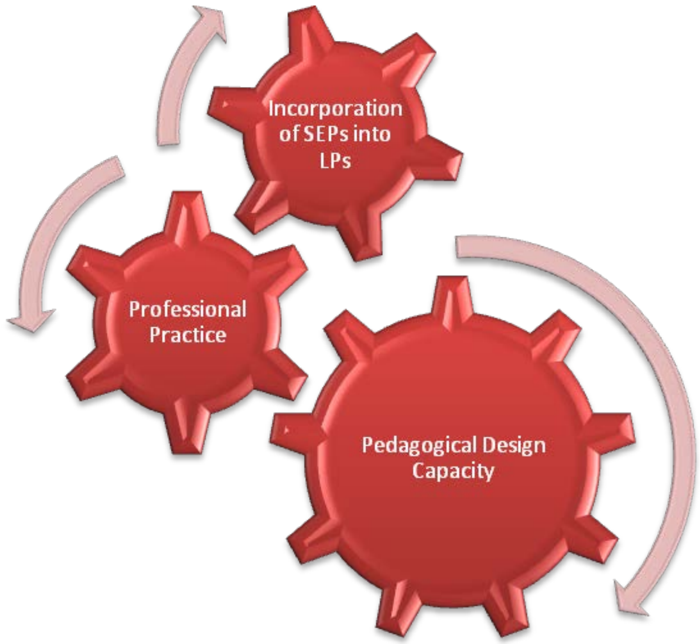

Figure 1.1. A model of how professional practice may help to bridge PDC for PSSSTs' ability to incorporate SEPs into lesson planning.

The change process is going to require that teacher educators develop methods and techniques to help facilitate the change. In this study, I will report on how an intervention with PSSSTs influenced their capacity to plan for lessons that incorporated SEPs. To build context, I review pertinent research that describes why incorporation of SEPs into classroom lessons is important, why it presents difficulties for teachers, and how a teacher’s knowledge, beliefs, and experiences with science, influence his/her PDC.

In the next section, I will describe the intervention in which the PSSSTs participated. This intervention provided opportunities for the PSSSTs to engage as learners in contexts where the instructor modeled target pedagogy (i.e. engaged PSSSTs in SEPs) and provided opportunities for them to design similar lessons for their own students. Finally, I will describe the data sources and methodology of the study and present the findings.

1.1 STATEMENT OF THE PROBLEM

The most challenging role PSSSTs face as they enter the profession may be that of the change agent. PSSSTs are asked to implement new reform pedagogy while learning and respecting the practices of veteran teachers (Friedrichsen, Munford, & Orgill, 2006). The tension lies in the correspondence between school science and how professional science is practiced. PSSSTs are expected to teach canonical content knowledge while simultaneously representing science authentically - a feat that most experienced science teachers have not yet mastered (Capps & Crawford, 2013).

Science as practiced in schools is epistemologically authoritative (Scott, 1998), with teachers acting as the authoritative figure and students receiving ‘a rhetoric of conclusions’ (Schwab, 1962). Pedagogy is often enacted using directions that are to be followed, facts that are to be memorized, and concepts that are to be applied. Classroom discourse often falls into a pattern in which known answer questions are asked and students try to guess the correct answer (Lemke, 1990).

These practices are often perceived as necessary in schools to maintain logistical continuity and discipline, but are inconsistent with recommendations within science education reform movements of the last few decades. Reformers have been pushing to make school science education more authentically scientific (Lee & Songer, 2003) by making the work in which students engage resemble the work of scientists. The NGSS advocates this by explicitly describing the practices of scientists and engineers (the SEPs) and promotes the learning of canonical scientific content through engagement with the SEPs.

Reformers have suggested various approaches to meeting the goal by focusing on curriculum structures that support teaching epistemic practices of science (Enfield, Smith, & Grueber, 2008; Stewart & Rudolph, 2001), using tasks with anomalous data instead of simple inquiry tasks (Chin & Brewer, 1998; Chinn & Malhotra, 2002), and creating conversation structures around modeling activities (Windschitl, 2008; Windschitl, Thompson, & Braaten, 2008b).

These reform efforts have aspects of science practice that we want teachers to engage with their students, however, PSSSTs may simply not know how to implement SEPs into their own classrooms. In the next section, I will provide background concerning science practices as well as how teachers develop capacity to teach practices.

1.2 BACKGROUND

The new standards framework from the National Research Council (2012), entitled, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (now adopted and referred to as the NGSS), outlines important scientific and engineering practices, which include: asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations, engaging in argumentation from evidence, and obtaining, evaluating, and communicating information. (The Framework and the NGSS share the same SEPs.) The NGSS calls on teachers to engage learners in these practices as they develop knowledge of scientific phenomena and canonical disciplinary ideas.

1.2.1 Pedagogical design capacity

A useful term for the development of capacity in planning pedagogically appropriate and authentic events is *pedagogical design capacity* (PDC). PDC was coined by Brown (2009), who states that it is the ability to perceive and mobilize existing resources in order to craft instruction contexts. This study occurred in a context where the explicit goal was for PSSSTs' to develop PDC, specifically to develop PDC as it pertained to creating learning contexts for students (grade 7 -12) to engage in SEPs while learning disciplinary ideas.

1.2.2 Supports for teachers engaging in SEPs

While the NGSS is intended to help teachers authenticate the science curriculum, there is little research on how teachers will use or interact with this guide. What is known is that PSSSTs may need what Grossman, Compton, Igra, Ronfeldt, Shahan, & Williamson (2009) called *representations of practice* so that they can make a concerted effort to *approximate the practice*. This can be facilitated by the teacher educator *decomposing the practice* (Grossman et al., 2009) in an effort to develop representations and structure those approximations so that the PSSSTs can learn to recognize and name practices. Teacher educators that scaffold these educative supports allow the PSSSTs to develop their practice by grappling with those aspects they see as missing, and remove those practices that are not effective.

These and other educative supports have been shown to help pre-service science teachers (PSSTs). Duncan, Pilitsis, and Piegaro (2009) for example, found that PSSTs benefited from a consensus class list of criteria for critiquing inquiry-based instructional materials. This scaffolding provided support to the PSSTs even when the list was not readily available. The PSSTs reflected upon in the list and were able to demonstrate markedly better critiques. However, in another study by Beyer & Davis (2009), PSSTs stopped attending to those supported features when the educative supports were removed. External pressures, such as course requirements no longer requiring the supported feature to be enacted may have played a role in the feature's absence.

In this study, I investigated how PSSSTs interacted with educative supports in coursework (Secondary Science Methods 1) and within the context of planning for instruction at their field sites. That is, I studied whether the intervention was effective in bringing about consistent application of planning practices through the use of educative supports (use of the New Standards Framework, modeling targeted pedagogical practices, approximations of the practice, etc.). I documented whether PSSSTs who participated in an intervention implemented SEPs in assignments for their pedagogy courses; and whether they continued to implement the SEPs in their field placements when the external pressures to do so (associated with the coursework) were removed.

The intervention that the PSSSTs engaged in was intended to help them develop PDC, specifically, the capacity to create lessons in which students engage in SEPs. Using the Grossman et al. (2009) framework of decomposing the practice, the intervention provided the PSSSTs with pieces of the practice that were broken down into constituent parts. For example, during the intervention, PSSSTs worked with Wisconsin Fast Plants. Information provided to the

PSSSTs regarding the plant's development, its life cycle, how they were planted and how they have grown. The task for the PSSSTs was to list features about the plants in an effort to develop an organizing taxonomical scheme. Here the goal of organizing a taxonomical scheme is to make PSSSTs aware of the planning that is required to enact just one of the science practices listed in the NGSS, that of *Planning and Carrying Out Investigations*. In this manner, PSSSTs are able to concentrate on the one task at hand, learn the necessary vocabulary so as to be able to communicate effectively and pay deliberate attention to that practice.

The intervention was a series of classes where the instructors modeled representations of practice and then provided the PSSSTs opportunities to approximate those practices. For example, instructors engaged the PSSSTs as learners in a lesson where they develop a protocol for measuring plant growth using unconventional tools. Following this lesson, PSSSTs reflect on the instructors pedagogical design choices, such as the choice not to provide conventional measurements tools as a way of forcing learners to think hard about the relationship between the data they are seeking and the data that various tools actually capture. This reflection centered on one aspect of the practice. This decomposition of the instructor's practice was intended to allow the PSSSTs to think about how instructional design choices led students to particular ways of knowing, which in this case was the relationship between tool selection and the effect on data representations. In subsequent lessons the PSSSTs have opportunities to approximate these practices of pedagogical design by engaging their students in similar lessons, either by actually enacting lesson plans or imagining enactment as they wrote lesson plans.

1.3 THE STUDY

1.3.1 Targeted SEPs

The NGSS (2013) lists eight SEPs that are applicable to classroom work. This study will concentrate on three of these practices:

SEP 3. Planning and Carrying out Investigations

SEP 4. Analyzing and Interpreting Data

SEP 6. Constructing Explanations and Designing Solutions

The rationale for choosing the three SEPs was based on the alignment between the Learning Cycle and these three SEPs listed above. The learning cycle consists of *Engaging* students with an investigable question, having the students *Explore* by designing experiments that yield data that can be transformed in order to reveal patterns, and providing opportunities for students to develop and critique explanations (the *Explain* phase). These three SEPs were most consistent with what was deliberately represented and approximated and were easily embedded into the intervention. Figure 1.2 shows the overlay of the learning cycle and the three SEPs investigated in this study.

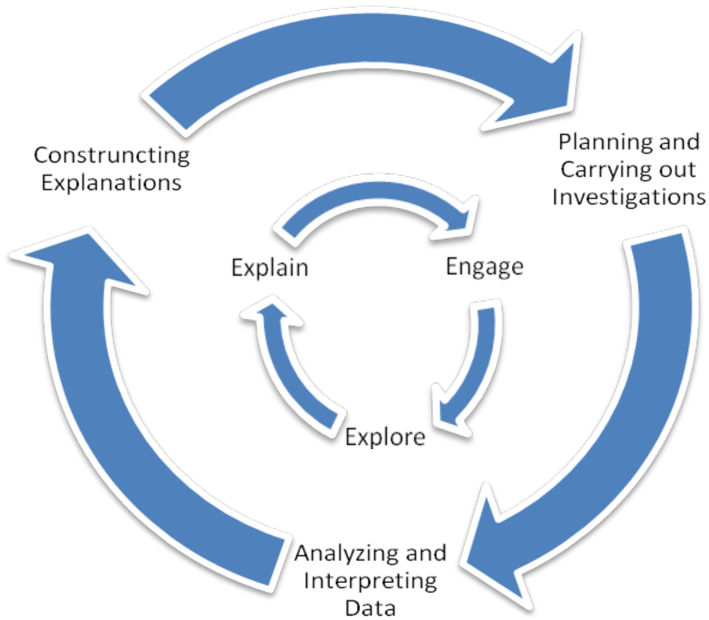

Figure 1.2. The overlay of the learning cycle (inner) and the SEPs (outer).

The intervention in this study consisted of model instruction, where PSSSTs participated as learners and subsequently had opportunities to analyze and unpack the instructional design practices of their instructors. The PSSSTs then had opportunities to approximate aspects of these planning instructional design practices through successive planning assignments.

1.3.2 Data collection

Lesson planning documents served as the principle source of evidence of PSSSTs' developing PDC. Two types of lesson plans were collected at various points throughout the semester. The first were lesson plans that were assignments written for the Secondary Science Methods 1 course. There were constraints associated with these plans, such as writing a lesson that aligns with certain parts of the learning cycle, as well as grading criteria. These criteria pushed PSSSTs to incorporate SEPs into their lessons. These lesson plans provided the evidence of whether the PSSSTs could successfully incorporate SEPs into their lesson plans. Later lesson plans provided evidence of whether the PSSSTs incorporated the SEPs when there were no requirements to do so.

The second type of lesson plan collected were those that the PSSSTs used in preparation for their regular daily instruction in their placement sites. These lessons were enacted with secondary students and needed to be not only solid theoretically, but must also be applicable in a real world classroom.

It should be noted that the first type of lesson plans mentioned above were also written with the intent of being used in the PSSST's classroom, but were not always used immediately because the PSSSTs were observing rather than teaching with their cooperating teachers when these lesson plans were written. PSSSTs could have also used materials provided by their mentor teacher or used the curriculum materials, however, they most likely needed to rewrite, modify, and/or cite other materials. Other PSSSTs developed lesson plans *de novo*. Both types of lesson plans were analyzed in this study.

PSSSTs were interviewed to provide feedback concerning their lesson planning and the ways in which elements of the intervention supported this work. Questions centered on how SEPs were encouraged throughout the Secondary Science Methods 1 course and how the PSSSTs were able to incorporate these SEPs into their lessons. Example questions included:

- What aspects of science are important for students to learn?
- What aspects of science are possible to incorporate during lessons?
- Are typical classroom laboratory exercises able to be adapted to include SEPs?

- What have you found helpful in authenticating the curriculum?
- What barriers did you encounter when incorporating SEPs into your lesson planning?

1.3.3 Measurement

For the purposes of this study, PDC was defined as the PSSST's ability to develop or modify lesson plans that have the potential to engage students in SEPs. PDC was visible when PSSSTs were able to critique and/or modify existing lesson plans or develop original lesson plans. The quantity of unique SEPs and sub-SEPs was used as the metric of incorporation. Counting the number of instances that unique SEPs or sub-SEPs were planned and/or enacted indicated the ability to incorporate these features into lessons, thereby demonstrating PDC. The *change in* the number of unique SEPs or sub-SEPs during the planning and enactment indicated the *level* of PDC, with high quantity indicating a strong PDC.

1.3.4 Research questions

The NGSS (2013) sets out a clear message of what SEPs should be incorporated into classrooms. This explicit document will influence curricular decisions well into the future. However, how teachers will interact with the recommendations is unclear. This study explored how teachers developed PDC around the incorporation of SEPs as they planned classroom lessons. The development of PDC was the goal of the intervention within the Secondary Science Methods 1 course. This study focused on whether the intervention influenced the PSSSTs' ability to write lesson plans for incorporating SEPs. More specifically, I investigated if, how, and when the PSSSTs developed PDC for incorporating SEPs and what aspects of the intervention, if any, were contributing factors. This was accomplished by analyzing PSSSTs' lesson plans and interviewing the PSSSTs using a stimulated recall protocol.

Measurement of PDC was determined by tracking PSSSTs' ability to modify or write lesson plans to include SEPs. My research questions are as follows:

1) Are SEPs represented in PSSSTs' lesson plans after viewing the SEPs? If so, which SEPs do the PSSSTs incorporate?
2) How successful are the PSSSTs at incorporating SEPs into their lesson planning during the intervention?
3) What is the longevity of the instructional intervention on PSSSTs' lesson planning when instruction is no longer given to incorporate SEPs? Which, if any, SEPs (or sub-SEPs) remain in the PSSSTs' lesson plans after the intervention?
4) What are the affordances or constraints that PSSSTs perceive when planning for SEPs? How do these affordances and constraints influence the incorporation of particular SEPs?

1.4 SIGNIFICANCE OF THE STUDY

One of the hopes of any reform initiative is that teachers can and will enact what is prescribed. In secondary science, the goal of moving towards more authentically scientific work has been marred by initiatives that unfortunately have not become standard practice. This study will contribute to the literature concerning how to help prepare PSSSTs to plan for enacting more authentic scientific and engineering practices. Preparation programs that work with PSSSTs will be able to use those aspects of the study that are successful and avoid investing time and effort into those that are not.

The results of this study will contribute to research into PSSSTs' lesson planning processes. Probing what helps or hinders PSSSTs when learning to implement and/or incorporate scientific practices will add to the research base. In addition, such knowledge might lessen the attrition rate of science teachers who initially do not feel they are capable of implementing reform pedagogy.

Lastly, this study tests the theoretical framework offered by Grossman et al. (2009) concerning the role of approximating the practices by decomposition and representations of the practice in the context of other frameworks (such as the learning cycle). If the Grossman model yields positive results in this study, it will help teacher educators make informed decisions concerning how new educators should begin to engage in high level practices that are practical in "real" classroom settings using a combination of the learning cycle framework and the Grossman framework.

1.5 LIMITATIONS OF THE STUDY

This study has several limitations. First, the design of the study is nested within the context of the PSSSTs' professional learning trajectory. The PSSSTs have finished course work from the summer term and the intervention occurs early during the fall term of the PSSSTs' academic year. The PSSSTs are concurrently enrolled in another course and are working at their placements within schools. Therefore, the PSSSTs are simultaneously interacting with other professionals and contexts outside of the intervention which could account for their performances in this study. This study also is built upon a chain of inferences that predicates that students learning about science is influenced by student engagement with SEPs, which is directed by PSSSTs' classroom practices. These classroom practices are influenced by the PSSSTs' planning practices which are influenced by the intervention. Figure 1.3 show the intervention is nested in the PSSSTs' professional learning and ultimately supports students learning science.

This study also measures planning of SEPs into PSSSTs' lesson plans by counting the number of unique SEPs and sub-SEPs, thereby giving a "more is better" feel to the use of SEPs. Appropriate use of SEPs for any given lesson requires examination of the context of the lesson, the ability of the students, the time appropriated for engaging students, as well as other contextual features. This study does not take any of these features into account, instead assuming that SEP use is the exception rather than the norm. Future studies that judge the appropriateness for a given SEP in a particular lesson will complement this research, but is beyond the scope of this study.

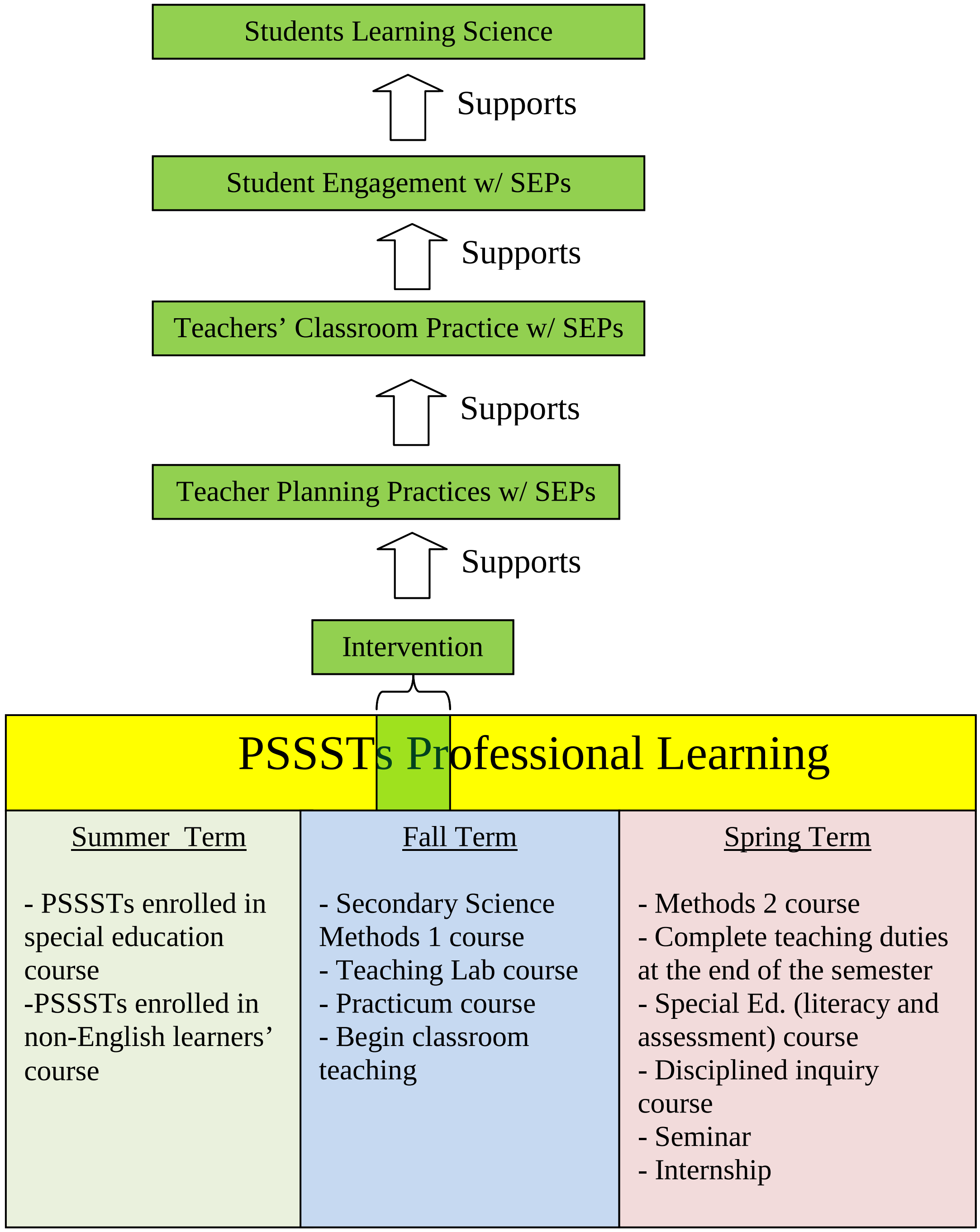

Figure 1.3. The intervention is nested within the PSSSTs professional learning trajectory and is predicated on ultimately influencing students learning science.

The PSSSTs enrolled in this study are in a prestigious Masters of Arts in Teaching (MAT) program, where all of the participants have degrees in science. Students entering the program have high grades, have mastered difficult scientific content, and have been scrutinized to ensure they have a very good likelihood of succeeding in the program. Therefore, it is difficult to know if the results of this study will generalize to PSSSTs in less prestigious programs, who may have entered with lower academic abilities, have taken less demanding course work, and who struggle with the rudiments of content knowledge in addition to the of rigorous pedagogical development that the graduate program demands.

In addition, many of the cooperating teachers that the PSSSTs are working with are experienced with reform pedagogy. Over the years, partnerships have developed between the cooperating school districts and the university, often because graduates of the university program are hired at these schools. In addition, the university plays a key role in influencing pedagogical practices, curriculum, and policy at these schools. For these reasons, this population may not generalize universally.

Another issue is the future enactment of lessons is not monitored, during the semester or longitudinally. This study is limited to planning practices, not actual classroom performance. Therefore, uncertainty will remain concerning the connection to planning practices and actual classroom practices.

1.6 ORGANIZATION OF THIS DOCUMENT

This first section of the paper has laid out a basic overview of the study, including the background information to contextualize the problem to be studied, the research questions to be answered, the significance of the study, and the limitations of the study. The next section, Chapter 2, will provide a deeper context for the study by reviewing the relevant literature. Chapter 3 will outline the methodology used in this study including how the data is to be collected and analyzed. Chapter 4 will provide results of the analysis. Finally, Chapter 5 will interpret the results, state conclusions, and make recommendations.

2.0 REVIEW OF THE LITERATURE

In this chapter, I will review what is known about PSSSTs' development of PDC around SEPs. In order to provide context for this study, several areas warrant review, including what is meant by PDC, why SEPs are deemed important, and how PSSSTs understand, interact with, and design lessons around SEPs. To be clear from the start, I will offer a description of PDC from Brown (2009), who states that PDC is the ability of the teacher to perceive and mobilize existing resources in order to craft instructional contexts. He continues, stating that teachers select, interpret, modify and accommodate curricular materials based on their own and their student's abilities, skills, beliefs, goals, capabilities, interests, talents, experiences, and limitations.

This definition plays a significant role in how this literature review will proceed because what PSSSTs know, believe, and value will influence the curricular materials they use, the manner in which the materials are presented to students, and the cognitive, conceptual, and epistemic work that can then be accomplished. Therefore, part of this literature review section will need to include PSSSTs' knowledge, beliefs, and abilities concerning SEPs. They will be examined in service to understanding how PSSSTs are capable of interacting with authentic scientific materials that incorporate SEPs. The term, SEPs, is relatively new to the literature, so the supporting terms that have a rich literature will need to be examined. This literature review will begin with the struggle to achieve consensus on SEPs along with the major initiatives that spawned the SEPs movement.

2.1 REFORM EFFORTS IN SCIENCE EDUCATION

The NRC's (2012) publication of *A Framework for K-12 Science Education: Practices, Concepts, and Core Ideas* (referred to hereafter as NGSS) is the culmination of several previous frameworks that focused on scientific literacy (AAAS, 1993), standards (NRC, 1996), and inquiry (NRC, 2000). In addition to important areas that needed defined, standardized, and explicated, major deficits were reported elsewhere, including classroom laboratory work (NRC, 2005), assessment (NAEP, 2010), and curriculum (NSTA, 2009). Each of these initiatives and reports contain disparate pieces of what are now called SEPs and all have contributed to the New Standards Framework.

The New Standards Framework differs from other the other reform work in its totality, approaching reform holistically. In this one document, classroom teachers should be aware of not only what content should be covered, but how to do so authentically. One of the premises of the New Standards Framework is that if teachers focus on content that is fundamental and has broad applicability across the sciences, then efficient and thorough coverage is possible.

The New Standards Framework consists of three dimensions that are recommended for science education and include common core crosscutting concepts in particular disciplinary areas and SEPs. The New Standards Framework stresses particular content and concepts to be mastered; however, coverage of content is not the most significant part of the New Standards Framework. SEPs, which have largely been neglected in both classroom practice and prescribed curricula, are a prominent feature of the New Standards Framework. It is these SEPs that are central to this study. In the next section, how SEPs situate in science education will be examined.

2.2 TARGETING SEPS

The New Standards Framework stresses scientific practice as a major goal for the reform movement. The practices of scientists and engineers has gone by many names in the past. Dewey famously used the term enquiry in a published article in Science magazine in 1910, stating, "Only by taking a hand in the making of knowledge, by transferring guess and opinion into belief authorized by inquiry, does one ever get a knowledge of the method of knowing." More recent descriptions of the practices of scientists include the term inquiry, which is the work of scientists (NRC, 1996), the underlying epistemology of why scientists practices as they do (often referred to as *the nature of science*) (Abd-El-Khalick, Bell, Lederman, 1998), what scientists know that makes them capable of engaging scientifically (called scientific literacy) (AAAS, 1993, 2009), and engagement in argumentation as the fundamental practice of scientists (sometimes referred to as authentic science) (Driver, Newton, Osborne, 2000). These are just few of the many descriptions of "what scientists do," which is exactly how Chinn and Malhotra (2002) parsimoniously describe science. Figure 2.1 shows that the SEPs are at the confluence of several ideas in science education.

Figure 2.1. SEPs are the confluence of several domains in science education.

The New Standards Framework attempts to “clean-up” the disparate terms that have been used in the past that alluded to what scientists actually know, do, and believe. In 2010, Feinstein stated that science literacy means everything to everyone and nothing to anyone. The New Standards Framework incorporates and explicitly describes eight practices indicative to science and its application fields (engineering) by distillation of previous work that describes science’s philosophical, social, and epistemological features.

While not exhaustive in their description of the practices that scientists engage, the New Standards Framework document depicts the most important practices. Table 2.1 lists the eight SEPs covered in the Framework.

Table 2.1. SEPs as described by the New Standards Framework.

Practice	Description
1	Asking questions (for science) 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 (for science) and designing solutions (for engineering)
7	Engaging in argument from evidence
8	Obtaining, evaluating, and communicating information

What is not known is how science teachers will interact with the SEPs when planning for classroom lessons. What is known about PSSSTs and their interaction with reform oriented frameworks will be covered in the next section

2.3 PSSSTS KNOWLEDGE OF SCIENCTIFIC PRACTICES

PSSSTs face a daunting task when they enter the field; that of attempting to achieve canonical content knowledge while simultaneously representing science authentically. It may only be a small exaggeration that the hopes and aspirations of the country lands on the shoulders of the PSSSTs for beginning the process of training world class scientists and engineers. However, early in their careers, PSSSTs experience, hold, and profess contradictory and unsubstantiated views of science and propagate them in their teaching (Lederman, 1992).

As PSSSTs begin teaching, they quickly recognize that a tension exists between coverage of content and teaching for deep understanding. The pressure to cover content often supersedes their desire to engage students more scientifically. Even if the PSSSTs attempt to teach using more constructivist teaching techniques, they are often deficient in the skills necessary to attempt such lessons and often return to more traditional classroom routines. Handcock and Gallard (2004) describe the duality that PSSTs hold of wanting to be student-centered in their approach and having students experience science, while simultaneously holding a teacher-centered transmission of knowledge belief. In fact, first year teachers are typically found to be teacher-centered, despite their proclamation of being inquiry-based (Brown & Melear, 2006).

Depending on their field experience, the beliefs of new science teachers may be challenged or reinforced. Windschitl and Thompson (2006) report that only 20% of their Master's students in science education reported opportunities to design and conduct independent investigations during their own precollege and college careers.

Regardless of their ideology, PSSSTs have a limited range of expertise in their science knowledge, pedagogy, and the ability to engage students productively with SEPs. Teachers are students themselves and a growing body of research shows that for students to learn the underlying epistemology of science, requires explicit instruction (Schwartz, Lederman, & Crawford, 2004). Paradoxical evidence may also exist here. Windschitl (2003) found that PSSSTs who had significant undergraduate or professional experiences with authentic science research were more likely to eventually use guided or open inquiry during their student teaching, not those had more authentic views or who reflected most deeply about their inquiry projects during a science methods course. While it is unclear if these PSSSTs had received explicit instruction concerning science during these experiences as students, interns, or employees, it is clear is that a sophisticated epistemology and beliefs of and about science are necessary, but not sufficient for teaching science authentically. Adding to this research is Kang and Wallace (2004), who reported that even if teachers possess a sophisticated epistemology, it is often not reflected in their teaching. Similarly, Ford and Wargo (2006) found that even when PSSSTs held sophisticated views of science practice, they simply felt it inappropriate for secondary classroom work.

What this research appears to be conveying is that what and how teachers teach is influenced by their experiences, knowledge, and beliefs. This may explain why in 2001, the National Research Council published a report entitled, Educating Teachers of Science, Mathematics, and Technology: New Practices for a New Millennium, which states that PSSSTs should be engaged in inquiry style courses. Adding confirmation to this idea is a study by Hubbard and Abell (2005), who found that pre-service elementary teachers who experienced inquiry science were able to recognize and learn from inquiry and better able to apply an inquiry approach to their lesson planning than teachers that had not.

Clearly, if SEPs are to be incorporated into classroom practice, teachers will need training on how to do so. The next section of this review will describe what is known about training PSSSTs to use SEPs.

2.4 PSSSTS PDC WITH SEPS

PSSSTs tend to interact authoritatively with their students. They give students directions that they are to follow, facts that the students are to memorize, concepts that the students are to apply, and evaluate students as being right or wrong on their answers. When teaching science, this may cause a tension in the goal of covering content and teaching SEPs. This is due to the fact that science is not based on a hierarchy of authority, but rather of data and evidence. This seeming incommensurability of controlling student behaviors while attempting to achieve an atmosphere of arguing with data has existed since formal science education began (see Dewey, 1964) and continues today. For example, when teachers were recently surveyed about their teacher preparation experience, Brown and Melear (2006) found that teachers stated that a course that focused on classroom management, authentic experiences, and lesson plan construction would be most beneficial. This intercept of conceptual, epistemic, and cultural knowledge and skill is what teachers find most difficult, and is what will be needed when attempting to incorporate science into their classroom performance. This is because integrating SEPs requires more than just providing factual content. It must answer questions about how we know, how we came to know, and why we should have confidence in it. Because of these added criteria, incorporating SEPs through authentic interaction will require more training than traditional teaching.

Despite having access to curriculum guides, having completed a plethora of science courses in college, and often possessing a degree in science, teachers find it difficult to enact reform based science. In the next section, I will review how reform based curricula similar to the SEPs are incorporated into the curriculum.

2.4.1 Teacher-curriculum relationship using SEPs

Attempts in the late 50's and the 60's to teacher-proof curricular materials (i.e. remove the teachers' agency from the lesson) were unsuccessful because teachers are not automatons; they interact with curricular materials and must be factored in as part of the curriculum (Remillard, 2005). This is the major conundrum that curriculum designers and administrators face when attempting to use the curricular materials as the change agent. The rational for removing the teacher was based on a deficit model, with the thinking being that teachers possess a skewed, weak, or incomplete view of science.. An example of this skewed view is given by Bianchini, Johnston, Oram, and Cavazos (2003) who report that PSSSTs view themselves as scientists. In reality, the overwhelming majority of PSSSTs are not scientists. This incorrect perception may seem marginally significant; however a teacher's practice is influenced by their beliefs (Jacobs, Yoon, Otieno, 2007; Lederman, 1992). Further influencing teacher beliefs and classroom practice are textbooks that portray scientists in a simplistic manner (van Ejck & Roth, 2008) and misrepresent the nature of scientific practice (Abd-El-Khalick, Waters, & Le, 2008).

In the defense of teachers, they cannot and should not be expected to have the same training, experiences, or habits of scientists, which requires copious amounts of time, research experience, and interactional time with scientists (Feldman, Divoll, & Rogan-Klyve, 2009). Asking the PSSSTs to engage, let alone teach the practices of scientists and engineers is a tall order and it should be a professional priority to elevate teachers abilities, but with the understanding that teachers are professional educators, not scientists. How teachers interact with the curriculum and how they view their place in that relationship will be reviewed in the next section.

Teachers' views and uses of curricular materials vary greatly. Some hold a traditional view of faithfully following the curriculum as it was written, others interpret the materials and modify them as they see fit for their particular students, and those that view the curriculum as a dynamic piece that is a tool for helping to mediate cultural meaning between members of a community. Ignoring teacher agency in the classroom can derail the curriculum's intentionality. Even if a teacher attempts to follow the curriculum exactly as planned, divergence from the intended curriculum will happen. This is because human subjects react differently, ask unscripted questions, misinterpret ideas, and have conceptions before viewing the new materials.

Teachers rarely rely solely on the textbooks or other parts of the curriculum to teach and their experiences color their understanding of those materials. However, the curricular materials that teachers use heavily influence how they enact their lessons. Unfortunately, curricular materials are often inherited, not chosen, and are deficient in strategies used to create an environment that encourages authentic teaching of SEPs. In fact, the American Association for the Advancement of Science (AAAS) conducted an instructional analysis of various science textbooks and found that the most science textbooks are deficient in providing a sense of purpose for leaning the content presented, ignore students ideas about the content, rarely if ever engage students with relevant phenomena or develop and use scientific ideas that promote student thinking about phenomena, experience, or knowledge, and do not assess students progress in learning these ideas (AAAS, 2005).

Curriculum materials should not be viewed as inert because teachers form a complex relationship with these materials that are based on the teachers' content knowledge, pedagogical skills, philosophical outlook, and their understanding of the scientific endeavor (Remillard, 2004; Brown 2002). Regrettably, as mentioned above, new teachers struggle with content, have naïve views of science, tend to hold a naïve-realist philosophy, and tend to teach in a manner that they were taught (see Davis, Petish, & Smithy (2006) for a summary of previous studies), which is usually authoritative (see Lemke, 1990; Scott, Mortimer, & Aguiar, 2006, Wells, 1999 for a discussion of traditional and authoritative stances in teaching).

In sum, teachers tend to be primed to hold an epistemological stance that views science as an unproblematic, linear way of accruing truth. Holding such a view would have little use for adopting an authentically scientific stance that espouse and use SEPs. In addition, traditional science curricular materials tend to focus on the end products of science: explanations, content, and the skills necessary to understand the explanations and content. It is therefore the job of the science teacher to *authenticate* the curriculum. This requires that teachers add to, truncate, and/or modify curricular materials in a manner that incorporates SEPs to the canonical content that the curriculum provides. This includes authenticating laboratory exercises, which are often designed so that faithful execution will yield uncontested results. It is this type of planning that will be described in the next section.

2.4.2 SEPs and lesson planning

New teachers (including PSSSTs) struggle with teaching inquiry, enacting their instructional ideas, and tend to be resistant to innovative practices (Davis, Petish, & Smithey, 2006). It therefore seems reasonable that beginning teachers will have difficultly engaging students' productively in SEPs. They will need support in developing strategies to do so. In the past, teachers have attempted to traditionalize inquiry lessons by treating it as content that is learned by following "the scientific method." The scientific method is easily placed into lesson plans, with its simple step-by-step progression that supposedly guarantees certainty if obediently followed. Windschitl, Thomson, and Braaten (2008a) state that for teachers, the planning and use of the scientific method is a victim of its own success, because treating science as a simple, linear method that unproblematically leads to successful completion of lessons, while antithetical to authentic science, has allowed teacher to successfully complete laboratory lessons for generations.

Unfortunately, those lessons learned by the scientific method are inauthentic, inaccurate, and reinforce a naïve view of the nature of science. In reality, scientists use many methods in complex ways, and are based on sciences epistemological underpinnings. A more fruitful representation of science is given by the New Standards Framework as a set of practices that the students are to engage as they are given and develop explanations about problems in nature. This New Standard Framework outlines important scientific and engineering practices, such as: asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations, engaging in argumentation from evidence, and obtaining, evaluating, and communicating information. How PSSSTs will use the New Standards Framework is unknown, however literature exists concerning how teachers develop the capacity to interact with curricular materials. This will be examined in the next section.

2.4.3 Developing capacity with SEPs

The SEPs described in the New Standards Framework may provide an educative tool for helping PSSSTs to teach authentically, however, enacting actual scientific and engineering practices with students will require training on how to plan for such work. To be clear, educative materials help with teacher and student understanding simultaneously, however, teachers learning about SEPs along with their students is no guarantee of successful teaching of those practices. Shulman's (1987) concept of pedagogical content knowledge (PCK) is an important model for understanding how teaching practices require more than a teacher's proficiency in content knowledge. PCK is about knowing where and why students have trouble learning content and having the tools necessary to help them overcome that trouble. Similarly, Brown's (2009) notion of PDC shows that content knowledge is also necessary, but not sufficient to design quality lessons. PDC is equally based in having expertise in developing instruction around the capabilities of the teacher and the student in a manner that maximizes the agency of both the teacher and the student. From this perspective, teaching is a designing activity. Lessons are not merely enacted, but developed with the student in mind; assessing their abilities, motivation, trepidation, as well as the potential outcomes. Designing lessons is not just planning for success, but planning for when trouble arises and having tools to help mitigate the situation.

Developing PDC is not a simple or linear progression, but one that is multifaceted. According to Brown (2009), it requires an ability to craft, modify, and use curricular materials in a manner that is effective for the objectives of the lesson, within the capabilities of both the students and the teacher, and encompasses the beliefs, talents, and limitations of the teacher. A teacher's self-efficacy is tied to the engagement of the curriculum, their pedagogical decisions, and their teaching stance. Remillard and Bryans (2004) found that a teacher's orientation influenced the way that curricular materials were used by teachers, thereby leading to different learning opportunities for the students. Brown (2009) adds that the ability to design lessons for students is also tied into teachers' beliefs, understanding, and experiences. How teachers develop PDC will be covered in the next section.

Remillard (1996, 2000) found that teachers learn from enactment of curriculum and not from the teaching guides. At most, however, curriculum materials offer the opportunities for teacher leaning. From this viewpoint, is not that science textbooks or the supporting science curriculum materials need to be calamitous to limit teacher learning, but rather they are never sufficient for teacher learning; they are just providing a piece of what is necessary for teacher learning about scientific work. The textbooks and the curricular materials provide the canonical content and the teacher is to provide the expertise to help students enact the materials in a manner that is scientific, but as mentioned above, teachers rely on the curricular materials they are enacting to learn. What is therefore needed, is to create a culture that incorporates SEPs into the curriculum. Since teachers are not scientists, they need to learn the habits and dispositions and underlying reasoning of why decisions are considered scientific in order to do scientific work. The New Standards Framework makes these practices explicit and is a tool that teachers can use for teaching SEPs.

Beyer and Davis (2009) point out that while educative supports can help PSTs to complete their lesson planning, it is insufficient to change practice. They found that when the educative support is removed, PSTs stop attending to those features. The reason for this may be that the PSTs are themselves students and are “doing school” rather than “doing science” (see Jimenez-Aleixandre, Rodriguez, & Duschl (2000) for a detailed explanation between “doing school” and “doing science”). Earlier work by Davis (2006) may help to explain this meaning. Davis found that pre-service elementary teachers felt that inquiry was most important for promoting student interest and not for engaging students in genuine scientific activity. That is, teachers had a misalignment of the purpose of scientific work in classrooms. They simply found it out of place. Interestingly, Davis (2006) reported that the pre-service elementary teachers possessed a sophisticated set of criteria for critiquing instructional materials but did not engage in substantive critique of how scientific content was represented in the classroom (even with explicit support). Ford & Wargo (2006) found the same type of behavior with PSSSTs, who understood scientific work, but felt it was out of place in the science classroom.

Beyer and Davis (2009) found that educative tools were useful to the PSTs, but the tool alone was not enough to keep the PSTs engaged in the targeted objectives when it was no longer mandatory. This demonstrates that PSTs may not have viewed the course work as necessarily representing authentic classroom work. This disconnect between theory and practice has plagued methods course for generations. Is there a model that might convince PSTs of the value of pedagogical study? The next section offers a model that attempts to represent both scientific and classroom practice.

Grossman et al. (2009) offers a model that may develop PDC by framing representations of practice. The general idea is to represent the practice in a manner that is not overwhelming to the PSTs. That is, by highlighting some aspects and back-grounding others, the PSTs can focus on a few aspects, gain proficiency, and then move on to other aspects. Representations of practice can be any portion of the practice that has analyzable data, such as lesson plans, student work, or videoed lessons. As the representations of the practice are analyzed, they may be decomposed into necessary acts that make up the practice. By breaking the whole into pieces, the cognitive demands of the totality of the lesson are lowered so that novices can concentrate on "seeing" aspects that experts routinely practice. Decomposing the practice, such as lesson planning, is a way of examining each constituent aspect of the practice and deliberating about it with the goal of understanding it. Decomposing the practice makes the important aspects visible so novices can engage with it to improve their own performance. Grossman et al. (2009) highlights the efficacy of this inauthenticity, where decomposition is no longer authentic, but rather just parts of the overall practice. This piece of the practice is only useful in the overall practice, but may be practiced so as to develop expertise with that one aspect which will later be incorporated into the classroom performance.

The final piece of the Grossman et al. (2009) framework is the approximating of the practice. Approximations of practice engage novices in a practice in a safe manner that allows for errors to be made, to be examined, and to become educative. Approximations of practice are similar to scaffolding in that they provide opportunities to engage in practices that are proximal to authentic practice, but with expert support to help remediate or guide future performances (see Vygotsky (1978) for his notion of zone of proximal development as a means of scaffolding). Approximations of practice can range from less authentic practice, such as critiquing past scenarios or role playing, to more authentic practice, such as student teaching (which remains an approximation of practice because a more expert teacher remains in the room). Approximations of practice are targeted and deliberate practices that focus on challenging aspects that experts complete without deliberation. Approximations of practice are in service to authentic practice, which is the ultimate goal.

The Grossman model, described above, is an apt lever for bridging the goal of incorporating SEPs into planning practices, which in this study, is a measure of the PSSSTs PDC. Figure 2.2 shows the relationship of the Grossman model as applied to science education for developing PDC around the incorporation of SEPs.

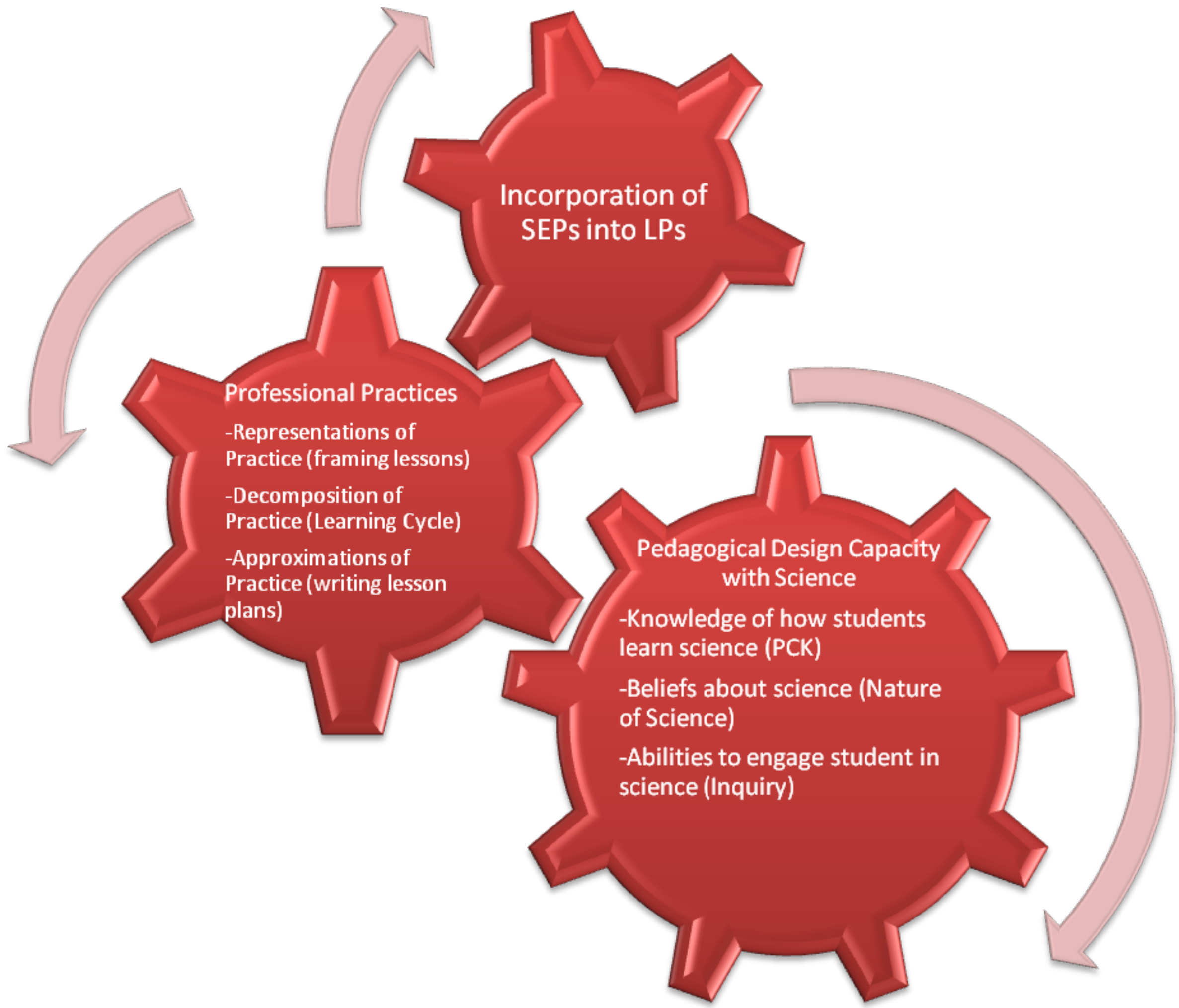

Figure 2.2. The intervention develops PDC by using the Grossman et al. (2009) model to help PSSSTs incorporate SEPs into their LPs.

This model may be applied to lesson plan development as a means of making change to PSSSTs' classroom performance and may be the change agent necessary to help teachers authenticate the curriculum. This will be examined in the next section.

2.4.4 Lesson planning as a change agent

Lesson plans are an apt change agent because they may serve as the representation of the practice, may be decomposed, and may approximate the practice (Grossman et al. 2009). There is evidence that instructional frameworks can enable pre-service science teachers to socially construct, synthesize, and apply their knowledge for enacting reform-oriented science teaching approaches. Schwarz & Gwekwerere (2006) report that K-8 science teachers embraced a reform oriented framework and used lesson planning as a tool for change, resulting in teachers moving away from traditional practices toward more authentic practices. Using the existing curriculum but authenticating it by using expert teachers to help represent, decompose, and approximate the SEPs may finally complete what Ball & Cohen (1996) called for over a decade and a half ago: curriculum that acts as a partner in practice.

This study used lesson plans as a means to assess, develop, and refine PSSSTs capacity to incorporate SEPs into classroom practice. The idea is not to simply erase and replace classroom practice, but to partner with it and make it more authentically scientific. The methods of how this was done are described in the next chapter.

2.5 THEORETICAL AND EMPIRICAL UNDERPINNINGS OF LESSON PLANNING

PSSSTs attempt to develop the skills, knowledge, and performances of their cooperating and other model teachers in a quest to become fully active members of the teaching community. While there is no set delineation mark that legitimates a teacher, the identity of a teacher does seem to naturally progress from being simply a student, to a teacher in training, and finally to becoming an effective and competent teacher. This transition can be framed in terms of progressing through stages, developing skills, acquiring knowledge, or accumulating time, all of which may be difficult to track. A complementary view of thinking of competence of a teacher may lie in the ability to plan lessons.

In this section, I make a theoretical and an empirical argument about why the intervention, as it is structured, can reasonably be expected to have a positive effect on the planning practices of PSSSTs. To do so, I will examine how both in-service and pre-service teachers plan lessons by examining the literature. In addition, I hope to provide insight as to why these teachers plan lessons as they do. This will require examination of how teachers learn planning practices, how they think about teaching and learning, and determine how malleable these views are. I will then make a case for lesson plans as providing leverage for teacher learning and their ability to enact that learning in the form of lesson plans. These arguments will be made in service of the Grossman et al. (2009) framework that is being used to help describe the rational and execution of the intervention. This process should provide insight pertaining to what initial coding categories might be expected for PSSSTs lesson plans before actually examining their lesson plans. To begin this review, I will present a few studies that help understand how PSSSTs encounter the field of education.

2.5.1 How PSTs develop planning capacity

Teachers often must act and react automatically and therefore their practice resists easy description. Roth (1998) succinctly describes practice as “unfold[ing] in time, irrevocably, and irreversibly. It is oriented toward the immediate situations, the here and now, and excludes all formal concerns" (pg 370). Many teaching practices are and remain unarticulated unless they are made conscious, framed or articulated as practice. Roth (1998) adds that, in their professional lives, teachers develop practices of which they are not aware, but are effective at dealing with the complexities of classroom life. Unfortunately, these practices may not include the reform framework that the education community is hoping for. Practices of PSSSTs are also seemingly elusive because they remain undeveloped, wrought with a long history of traditional practice as students, and are contorted due to the pressure from several disparate sources including their cooperating teachers, their university professors and supervisors, parents, and the curriculum of the school. In the following section, the empirical differences between in-service and PSTs will be reviewed.

2.5.1.1 PSTs initial planning practices

Science teacher candidates entering the profession have orientations that are of three central teaching goals: motivating students, developing science process skills, and engaging students in structured science activities (Talanquer, Novodvorsky, & Tomanek, 2010). These intended goals often manifest themselves in using hands-on activities that scaffold the science process skills that are to help make connections to the real world. However, actual teacher planning practices are not necessarily consistent with these findings. For example, S<nchez and Valc<rcel's (1999) study of practicing science teachers showed that content is the driving force behind planning. Once the content is selected, science teachers often use the curriculum guides to help plan activities, which usually involves looking through the textbook and the accompanying supporting documents to find more information. S<nchez and Valc<rcel (1999) continue stating that teachers modify activities, but rarely modify the content, feeling that the textbook presents the

conceptual structure that is not in need of revision. In a similar study with novice teachers, Deborah Brown (1993) reports that novice teachers tend to focus on procedural practices, which complements Shalvason (1987) who reports that both experienced and newly qualified teachers plan primarily with activities as the central element.

In-service and pre-service teachers show similarities in their planning orientations in that both plan around activities and content. However, there are some differences between in-service and pre-service teachers capacity to plan science lessons. Lederman and Gess-Newson (1991) found that during student teaching, PSTs focused on learning and applying pedagogical content knowledge gained from their cooperating teachers which included the use of analogies, demonstrations, and activities. In this manner, PSTs seem to focus on learning a series of behaviors and actions that help them enact their own classroom performance. In addition, PSTs reported feeling the pressure of learning content knowledge while simultaneously planning experiences with cooperating teachers, the class textbook, and accompanying curriculum guides (Brown, 1993). Comparatively, in-service teachers have much more class time experience, and therefore would be expected to have developed a stronger sense of identity, more familiarity with the content, and have knowledge about what has been successful in past attempts and what has not. These practical matters need to be connected to theoretical aspects of teaching, learning, and planning. This will be completed in the next section.

2.5.2 Theoretical aspects of PSTs planning

A teacher’s education begins when they are students themselves. They are formally brought into the teaching domain by the instruction of their cooperating teachers and their professors. The views of PSTs may become entrenched in the practices of their teachers and their experiences.

Therefore, PSTs that are taught science using traditional practices may view the domains of science and teaching in a traditional fashion. (The evidence seems well documented in the nature of science literature reviewed earlier.) From the previous review, it seems clear that many facets are required to plan and enact lessons, which includes the practices of teacher, the school community, and the guiding supplementary materials that make up the curriculum. In this manner, planning practice may correspond with performing as a legitimate member of a community (Lave & Wenger, 1991) and PSTs may attempt to authenticate their position in that community by mimicking their cooperating teacher, who may or may not represent the practices of the scientific community.

Teacher learning and teacher practice are different things and yet remain inextricably linked. The reason for this is that they constitute different spaces within the same field. There is a difference between learning and teaching, where the first offers affordances to become opportunities for the improvisational development of practice and the second limits, structures, and controls what is learned (Lave, 1990; Lave & Wenger, 1991). Learning, from this situative perspective, is not a practice that is a simple linear process in which rules are learned, and applied in a particular sequence. Teaching, like learning, are comprised of practices situated in culture, both locally (within a particular school) and globally (within a domain). Similarly, planning practices are linked, yet not completely dependent on the conceptions a teacher holds of learning and teaching.

An example of this seeming incommensurability is that of valuing a constructivist philosophy while teaching in a traditional manner. This dichotomy is not an unusual situation for many teachers and may be explained from cultural ecology of the teacher (Kang & Wallace, 2004). (Cultural ecology includes ontological, epistemological, and other beliefs situated in a domain or culture.) Those teachers that hold a traditional view of learning and teaching often embrace a behaviorist perspective in which learning is represented by breaking the complex into simpler, *decontextualized* components and rules that can be learned independent of the whole. From this perspective, practice is a set of logically sequenced skills, rules, and behaviors that if applied correctly, represents the essence of the domain and the path to truth. S<nchez and Valc<rcel (1999) report that science teachers, in general, remain enamored to this transmission view of knowledge, which demonstrates how far most teachers are from a more reform oriented, constructivist philosophy. In the next section, the possibility of changing teachers planning practices will be explored.

2.5.3 Changing science teachers planning practices

In previous sections, the reviewed literature held that in-service science teachers' practices are often antithetical to reform practices. Therefore, if PSTs emulate in-service teacher practices, then it seems unlikely that reform frameworks will be effective at transforming PSTs practice. Windschitl, Thompson, Braaten, and Stroup offer hope in their 2012 study that makes the case that once practices are shown to be successful, the educational community (teachers, teacher educators, etc.) will build-up, incorporate, and ultimately reshape current practice. Martin del Pozo, Porlan, and Rivero (2011) concur, demonstrating that prospective teachers' conceptions of school science content, while resistant to change, could be changed during teacher education courses from a more traditional, simplistic, teacher knowledge centered conception to one that is more pupil centered and epistemologically differentiated. Therefore, it appears that PSTs as well as in-service teachers can change their teaching practices if sufficiently supported. This should not be surprising in the wake of the study completed by Jeanpierre, Oberhauser, and Freeman

(2005) that showed that teacher practice does change with professional development experiences which include numerous opportunities for practice in tangible and accessible ways with deep science content and process knowledge.

Prospective teachers of science are readily transformed, unfortunately in a direction that is against reform. That is, PSTs often identify themselves as being somewhat more constructivist than they are, but they tend to teach in a more traditional manner once they begin teaching, often citing the impracticality of teaching in a more constructivist manner (Porlan & Martin del Pozo, 2004). This seems to show that while prospective teachers may hold constructivist teaching as exemplary teaching, they seem to fall back to the tried and true manner in which they were taught. This is consistent with Handcock and Gallard (2004), who report PSTs hold a dual, yet opposing belief in student learning as experiential and teaching students via transmission.

2.5.4 The case for lesson plans as a change agent

How can PSSSTs be moved towards more reform oriented practice? The answer may be in the lesson planning which may provide insight into how teachers approach content, think about teaching and learning, and may even expose pedagogical content knowledge. Da-Silva, Mellado, Ruiz, & Porlan (2007) state that teachers' change in conceptions of nature of science, teaching, and learning is dependent on that teacher's ability to reflect on these practices. PSSSTs' lesson planning can provide insight about their thinking as they write about how they think students will interact with the content, how they will create an environment in which the learning can take place, and how they intend to assess student learning. Therefore, lesson plans may provide leverage for engaging teachers in reflection that usually remains personal.

From a teacher educator and a research perspective, lesson plans have the additional benefit of increasing the reflective time as compared to enacted time. That is, lesson plans can be used as longer period "chunks" than evaluations of classroom observations, thereby allowing insight into the teachers' decisions about sequence and relationships between activities and topics as well as their assessment strategies which are not commonly evident when observing a single class period (Jacobs, Martin, & Otieno, 2008). In essence, lesson plans have a higher *n*-value (statistical value) than actual classroom observations, thereby giving a more accurate overall representation of a teacher's practice that may otherwise be skewed by a single observation.

2.5.5 Initial coding categories that might be expected from the literature review

From the previous literature reviewed, I would not expect to find SEPs in the planning of PSSSTs because these practices are not usually addressed in textbooks, most cooperating teachers do not expend time teaching them, and curriculum rarely sets these as objectives. However, PSSSTs do plan around activities and many attempt to use hands-on activities, so it is possible that students will analyze and interpret data. If they do so, I would not expect in-depth analysis nor would I expect many features for that SEP. The one feature that is likely to be present is: *Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information and computer technology to collate, summarize, and display data and to explore relationships between variables, especially those representing input and output.* Many activities, including traditional activities, end with directions for students to create a graph of the data. According to the protocol that I developed in the methodology section, I would therefore mark this SEP as being present if a graph were called for and questions were asked that required students to ponder the relationship displayed by the graph.

2.5.6 Predicted positive effect of the intervention

The intervention is characterized as such because it offers a path towards the reform. Aspiring science teachers may be motivated to teach in a manner that is different than a traditional teacher, however, without an intervention, most PSSSTs will, according to the literature review above, eventually resort to and adopt a traditional stance. The intervention situates PSSSTs into a simulated working classroom that is not entirely different than the one they are currently student teaching in, in that there are students who are engaged with a more expert member who is attempting to help generate an environment in which understanding can grow. However, the common criticism leveled at education programs is that there is a "real" classroom out there and anything other than that classroom is a different situation. This is a valid concern and one that needs to be addressed if this intervention is theoretically feasible.

There has long been a charge leveled at the situative perspective, in which a mechanism for transfer is lacking because all learning occurs in some situations and how those situations are arranged matters (Greeno, 1998). [Note: Greeno (1998) summarizes the situativists' perspective as learning as effective participation in practices, which differs from the behaviorists' perspective of learning in terms of acquisition of skill, and from the cognitivists' perspective of thinking in terms of learning concepts and understanding general strategies.] Recent research from Engle (2006) proposes that framing interactions can lead to generative learning, which is learning that results in flexible use in a wide range of future situations. In this perspective, framing can create an intercontextuality, whereby contexts become linked to one another. The frequent reference to past contexts (such as those in the intervention) increases the chances that it will be applied to future contexts. How to go about that may be informed by the Grossman et al. (2009) framework which can build on this situative framework, where representations are about sharing the understanding of questions, hypothesis, and arguments in the domain (Greeno, 1997). The Grossman et al. (2009) framework will be reviewed below as well as its use in the intervention.

2.5.7 The Grossman et al. framework and the intervention

Grossman et al., (2009) provides a framework they have termed *relational practice* that identifies three key concepts for relating professional practice to professional theory of practice. These include representations of practice, decomposition of practice, and approximations of practice. Representations of practice comprise different ways that practice is utilized in a profession, often in ways that make practices visible to novices. Decomposition of practice involves breaking down practices into constituent parts for the purposes of teaching and learning. Approximations of practice refer to opportunities within professional education for novices to engage in practices that are more or less proximal to the actual practices of a profession.

2.5.7.1 How planning is represented during the intervention

During the first day of the intervention, the teacher educator represents the practice of planning by focusing on SEP 3, that of *planning/carrying out investigations*. The representation of this practice is one of significant work that must be completed before students enter the classroom. During this portion of the intervention, the PSSSTs were essentially modeling student behavior themselves as they investigated Fast Plants. As the activity progressed the teacher educator stopped the activity in an effort to provide the PSSSTs an opportunity to reflect on the planning required by the teacher educator to conduct this type of lesson. In particular, the teacher educator asked the PSSSTs to think about the preparation needed to conduct such a lesson including anticipating questions, responses, and outcomes. This is in addition to more typical aspects of teaching that require teachers to have background information ready for the students, having directions and worksheet printed, having materials available, and pacing appropriately to ensure that the lesson fits into the allotted class time.

The teacher educator invokes the rubric for lesson planning as a way to help the PSSSTs to develop an eye for lesson planning as a professional practice. Each aspect of the lesson plan is represented on the rubric, giving a full view of the breadth required to cover all aspects of planning. While each aspect is not described in detail, the PSSSTs can see that planning lessons is more than just listing objectives, stating which pages of a textbook are represented, and ending with a statement of closure. By modeling a lesson, explicitly describing the planning of the lesson, and having students reflect on their own planning practices, the teacher educator gives the PSSSTs a professional vision of what high quality planning looks like.

2.5.7.2 How planning is being decomposed during the intervention

Decomposition of practice is not the behaviorist's atomization of breaking the complex into decontextualized parts that no longer resemble the whole. Here decomposition is more akin to grain size. In this manner, the Grossman et al. (2009) framework aligns with the situative perspective and is not rooted in acquisition of disembodied skills, but rather the taking the totality of the complex and focusing on one piece of the practice. This is more aligned with examining the chorus of a song rather than examining the how sound emanates from just one instrument. The wholeness remains, however, the examination of this one aspect allows for reduced complexity. It is in this manner that the teacher educator helps the students decompose the planning of high cognitive demand lessons. High cognitive lessons in science are those in which complexity is a necessary aspect, much like the work of scientists. Scientists' work encompasses the practices of the field and operates within a complex web of epistemological underpinnings, accepted methods of inquiry, and strict procedures of representing the work in an empirically verifiable manner. Similarly, PSSSTs work in a complex field with unpredictable cliental, a plethora of potential problems, all within a dynamic school setting that pulls the PSSSTs in multitude of directions.

Focusing on a particular class lesson is itself complex, so the teacher educator reduces the complexity by helping the PSSSTs focus on how to begin a lesson. More specifically, the teacher educator helps the PSSSTs think about various aspects of planning lessons. For example, how to begin engagement in high cognitive demand lessons requires a way to engage students. Once engaged, how does the teacher allow the students to explore the problem at hand, to posit ideas, to attempt to apply these ideas, and extend these newly learned lessons in order to demonstrate understanding?

During the intervention, the teacher educator has the PSSSTs work through a task that has them attempt to predict the moon cycle for future times. This is a highly cognitive task that requires the PSSSTs to develop physical, mathematical, and conceptual models of the motion of the moon, think from both an Earthlings reference frame and one that observes the motion from space, and to develop ways of explaining the phenomena in pedestrian vernacular of time.

After the PSSSTs work through the problem, the teacher educator helps decompose the planning of this lesson from the teachers' perspective. The teacher educator uses tools such as the Learning Cycle and the 5-E model (Engage, Explore, Explain, Apply, and Extend) in an effort to introduce vocabulary necessary for the PSSSTs to develop a professional vision of the planning process. For aspects of the 5-E model of the learning cycle, the teacher educator describes the planning that was necessary, the anticipation of the problems that could have arisen, the pedagogical and scientific goals for each aspect of the 5-E model, and how these goals can be written in a lesson planning document.

The teacher educator then explicitly connects the SEPs to the learning cycle by asking the PSSSTs to identify particular aspects of the lesson with both portions of the 5-E model and particular SEPs. The message is clear – that planning with the learning cycle enables for the design opportunities for students to engage in SEPs. It is the organization and planning that scaffolds student learning that not only allows for the opportunity to engage in SEPs, but to do so with increased instructional coherence.

2.5.7.3 How planning is being approximated during the intervention

The PSSSTs approximate authentic planning practice by writing lesson plans that are analyzed in the Secondary Science Methods 1 course. While these lessons are written for the Secondary Science Methods 1 course, the lessons may also be used during the PSSSTs teaching placements. The benefit to the PSSSTs of approximating the practice of teaching a lesson through planning is that they are not placed in a position where errors will have detrimental effects on their students, nor face the humiliation of a failed lesson. Within the confines of the Secondary Science Methods 1 class, students may experiment by applying SEPs to various parts of the lesson, integrate them with the 5-E model, and think through planning of high cognitive demand aspects of the lesson.

Approximations of planning are not independent of the representations of planning or decomposing of planning, but are in fact facets of the practicing planning practices. Novice teachers often do not know what look for, what to target, or how to do so when planning lessons. To approximate planning of high cognitive demand lessons requires that the PSSSTs apply lessons learned from the intervention, such as those model lessons where the teacher educator represented the practice. Additional lessons were learned when the model lesson was decomposed into the planning practices that made the lesson possible. The three aspects of representing, decomposing, and approximating practices are not hierarchical, sequential, or mutually exclusive, but rather different ways of investigating practice. As such, there is no set method for their use or application. The three act synergistically to help elevate the level of practice, which in the case of this intervention, is in service of planning high cognitive demand lessons that incorporate the SEPs.

The PSSSTs wrote preliminary lesson plans for class with the explicit instruction of attempting their best work at planning for incorporating at least one SEP. The PSSSTs uploaded a lesson to the lesson planner and brought a hard copy of their lesson to the intervention. Here, they exchanged and critiqued each other's plans by physically cutting them into pieces that corresponded with different aspects of the SEPs and lesson planning aspects. Lessons learned from this portion of the intervention were then to used in revising the lessons. This allowed the PSSSTs to approximate the practice of planning a lesson. Their first attempt resulted in an awareness of what was in need of improvement, including what to eliminate, what to add, and/or what to modify. The idea is that novices inevitably make mistakes and approximating the practice allows for feedback that helps improve practice, which in this case was about improving lesson planning around SEPs.

2.5.8 Conclusion

Science is a social endeavor and learning scientific practice can be thought of as becoming oriented with the ways of speaking, thinking, and acting as a scientist. The teaching of science is similarly a social process and the convergence of the teachers' intent and the students' performance are linked together during classroom lessons. It is through lesson planning that teachers can improve the chances of engaging students in high cognitive tasks that can help authenticate the curriculum. The model by Grossman et al. (2009) offers a productive view of how PSSSTs can practice their practice, which in this case is planning lessons that incorporate SEPs.

The Grossman framework is within the situative perspective and views practice as the intersection of both the individual practitioner and the professional community, thus allowing the messiness and the complexity of authentic practice as human agents interact as students of science. This is in sharp contrast with the behaviorist and cognitive perspectives that tend to view learning as an individual, simple endeavor made of schemes and behaviors that ignores the complexity of learning, its context, and its authentic application.

Others have used the Grossman framework, including Smith and Stein (2011) and Cartier, Smith, Stein, and Ross (2013) who provide a framework for orchestrating meaningful discourse in mathematics and science classrooms respectively. They offer five sub-practices of anticipating, monitoring, selecting, sequencing, and connecting, some of which were used in the above intervention. It is, however, the representation of practice, the decomposition of practice, and the approximation of practice centered on planning of secondary science lessons that we find most useful. This coupled with the 5-E model of planning with the goal of incorporating SEPs help PSSSTs participate within a domain of professional teaching practice.

I have made a theoretical and experimental case for why the intervention, as designed, will likely have a positive effect on the PSSSTs planning practices. Attending to the kinds of situations that both students and teachers will be engaged is important if progress is to be made in science education. Scientists, themselves are both teachers and students in that acting scientifically means to both contribute to and gain understanding about the natural world. The SEPs require students to participate in the practices of science. By developing high level instructional practices that increase teachers’ ability to plan lessons is a meaningful contribution to pushing SEP incorporation.

3.0 METHODOLOGY

Chapter 1 provided the motivation, rationale, and arguments for why PSSSTs need to incorporate SEPs into the existing curriculum. Chapter 2 reviewed the literature concerning how teachers develop PDC as well as the barriers to that the change process. Both chapters 1 and 2 made a case for why this research is necessary. In this chapter, I will describe the design and methods employed to complete this study.

The first section describes the purpose of the study, including the rational for working with PSSSTs in the development of PDC. The next section describes the context of the study, including the specific research questions. The population section then describes the Secondary Science Methods 1 course and the PSSSTs various placements. Data sources will be explained in the next section, including how the data are selected and how data will be collected. This includes describing the intervention and the lesson plans written by the PSSSTs that will be analyzed. How the data and lesson plans will be analyzed will then be explained, including how the coding system was developed and how it will be used to analyze lesson plans. This coding system will be based in the researcher's perspective, also known as the etic perspective (see Pike (1954, 1967) for a description of etic and emic). The emic perspective, or the PSSSTs' perspective, will be explored in the final section where I describe the intervention and the corresponding interviews that will take place with the PSSSTs at the end of the semester.

3.1 PURPOSE OF THE STUDY

The purpose of this study is to examine how PSSSTs develop PDC around SEPs. Pedagogical design capacity is the ability to perceive and mobilize existing resources (curricular materials, worksheets, presentations, etc.) in order to craft instructional contexts (Brown, 2009). In this study, PDC will be defined as the PSSST's ability to plan for engagement with SEPs, plan supports that will elicit student thinking with SEPs, and anticipate student responses about SEPs. In this manner, PDC is the ability to make visible potential problems and offer potential solutions during the planning phase of instruction, which includes not only writing of formal lesson plans, but also developing, using, and modifying other artifacts and tools (worksheets, representations, laboratory assignments, etc.) that will be used in support of the lessons.

The SEPs that are specifically targeted in this study include *planning and carrying out investigations* (SEP 3), *analyzing and interpreting data* (SEP 4), and *constructing explanations and designing solutions* (SEP 6), all of which are proposed by the National Research Council's (2012) New Standards Framework. These three SEPs were chosen because they aligned with the instructional support provided by the Secondary Science Methods 1 course (see Figure 1.2) and the intervention at the beginning of the course (both will be described later in this chapter).

Analyzing PSSSTs' lesson plans and supporting artifacts will be the primary source of data for this study. The lesson plans and the supporting artifacts will additionally provide valuable feedback about the efficacy of the educative supports for the course designers. In the next section, the design of the study will be explained.

3.2 DESIGN OF THE STUDY

PSSSTs in the MAT program at the university in this study, enter the field as interns, slowly accruing the roles and responsibilities of a classroom teacher. The PSSSTs learn to direct, motivate, and control their classroom practice through planning lessons. This study will analyze how PSSSTs plan lessons that incorporate SEPs before, during, and after experiencing an *intervention* that occurs during the first methods course at the university. In particular, this study will analyze the number of SEPs and sub-SEPs that are incorporated by the PSSSTs. Of critical importance is the longevity of usage of the SEPs by the PSSSTs, which has been discussed in previous chapters as being problematic.

This study uses a mixed methods design with qualitative and quantitative metrics that measure how SEPs are planned for in PSSSTs' lesson plans. Baseline measurement will begin as the PSSSTs begin the Secondary Science Methods 1 course, which occurs at the beginning of the MAT program. Previous studies, outlined in the literature review in chapter 2, demonstrate that PSSSTs do not regularly attend to epistemic features of science, so the occurrence of the SEPs in their lesson plans may or may not be present in the PSSSTs' lesson planning.

The purpose of the intervention is to bring attention to the SEPs and to help PSSSTs plan for incorporating SEPs into existing lessons as well as newly developed lesson plans. The efficacy of the intervention will be measured during the semester to see how PSSSTs are planning for SEPs. The level of utilization and incorporation of the SEPs will be monitored throughout the course. No other direct instruction will be provide for incorporation of SEPs into the PSSSTs' lesson plans other than the intervention.

Quantitative analysis will include counting the number of SEPs and sub-SEPs that are incorporated in PSSST's lesson plans. Qualitative analysis will include interviewing PSSSTs about their incorporation of SEPs into the planning process. Using both qualitative and quantitative methods will provide both etic and emic perspectives. In summary, the research questions are as follows:

1) Are SEPs represented in PSSSTs' lesson plans after viewing the SEPs? If so, which SEPs do the PSSSTs incorporate?
2) How successful are the PSSSTs at incorporating SEPs into their lesson planning during the intervention?
3) What is the longevity of the instructional intervention on PSSSTs' lesson planning when instruction is no longer given to incorporate SEPs? Which, if any, SEPs (or sub-SEPs) remain in the PSSSTs' lesson plans after the intervention?
4) What are the affordances or constraints that PSSSTs perceive when planning for SEPs? How do these affordances and constraints influence the incorporation of particular SEPs?

In the next section, the population for this study will be described.

3.3 POPULATION

Eleven graduate students who are enrolled in the MAT program in a large research university in the mid-Atlantic region were invited to participate in this study. The MAT program is an intensive 12-month endeavor that includes rigorous course work and a ten-month internship with a cooperating secondary school. All MAT students enrolled in the program possess a science related degree and will receive a Masters degree and a teaching certification upon completion of the program. A prerequisite to entering the MAT program is completing a course that covers rudimentary aspects of teaching. Secondary Science Methods 1 is the methods course in which the above described intervention is nested and is the first methods course that the PSSSTs participate in the program. The Secondary Science Methods 1 course will be described in the next section.

3.3.1 Secondary Science Methods 1 for PSSSTs

The Secondary Science Methods 1 course primarily targets planning practices of the PSSSTs. The course entails 60 hours of instruction; meetings occur weekly for 2.5 hours in the evenings with three 8-hour workshops on the weekends. The PSSSTs are responsible for writing three individual lesson plans and one group unit plan, all of which are to be submitted to the professor electronically on specified dates. Instruction about planning is a primary activity of Secondary Science Methods 1, including planning for authentically scientific lessons. Modeling of science practices as well as instruction for identifying science practices in sample lessons will be primarily completed during the intervention. PSSSTs are also required to write reflective pieces that are in service of supporting incorporation of science practices into the planning of lessons. This includes writing critiques of their own lesson plans and the lesson plans of other PSSSTs.

The PSSSTs in this study are enrolled concurrently in Secondary Science Methods 1, a Teaching Lab course, and a Practicum at the university. All three courses have been designed to complement one another, with Secondary Science Methods 1 focusing primarily on the planning of lessons.

PSSSTs who will be asked to participate in this study will be interning in a large urban school district. The selection of interns will be within a single district, thereby serving strategically as a method for controlling the demographics that the PSSSTs in this study will be encountering. Collecting data from a single district should reduce the variation that often occurs between districts in terms of socioeconomic makeup, school culture, and the different policies and procedures that occur between districts. Therefore, PSSSTs will have reasonably equivalent placements, differing only in their cooperating teachers, which may also be a small variation due to the district having a common curriculum.

This study attempts to limit or neutralize difference among placements, which seems reasonable; however differences may occur and will be reported as they become apparent. The PSSSTs included in this study differ in grade level taught and in their science discipline, which is a potential source of variability. Placements of the teachers will also be in three separate buildings: a high school and two feeder junior high settings. The distribution of PSSSTs' disciplines, grade level, and level of secondary school are given in Table 3.1 below. Table 3.2 compares the demographics between these three schools.

Table 3.1. Distribution of PSSSTs in placement schools and discipline.

Discipline	Physics	Chemistry	Biology	Earth/Space	General
Grade(s)	11-12	10	8 - 9	8	7
School 1 (HS)	2	2	3		
School 2 (JHS)			1	1	
School 3 (JHS)					2

Table 3.2. Comparison of demographics and socioeconomic status between schools.

	Junior High 1	Junior High 2	High School
Demographics	85% African American 7% White	70% African American 17% White	30% African American 53% White
Economically Disadvantaged	79%	91%	64%

3.4 DATA SOURCES

In this section, I will describe the data sources and how they will be utilized to answer specific research questions. PSSSTs will be using an electronic planner that will include their lesson plans, worksheets, presentations, etc. The electronic planner will be available online and viewable by the professor of the course, the other PSSSTs, and the author of this study. Comments can be made by all users for each lesson plan. Therefore, all lesson plans written by the PSSSTs will be readily available for this study.

Embedded within the PSSSTs' lesson plans are artifacts, which include prewritten lesson plans, worksheets, PowerPoint presentations, laboratory assignments, and any other products that the PSSSTs use in support of their lessons. These artifacts will be considered part of the PSSSTs' lesson plans and will be examined to determine the PSSSTs' level of PDC. In this study, PDC is the inclusion of SEPs and/or the scaffolding of SEPs for students within lessons. Here scaffolding indicates the support of that students will need in order to develop a vision of the SEPs. This may include representing a scientific practice, decomposing the features of a scientific practice, and/or engaging discussions with the students about a scientific practice.

In addition to examining lesson plans of six of the PSSSTs, they will also be interviewed about their lesson planning and will be chosen to clarify what Agar (1994) describes as rich points in the data. These are events or happenings that occur when two cultural standpoints converge or differences in understanding occur. In this study, the view of the researcher and the view of the classroom teacher may not align and may reveal important aspects about teacher preparation, the views of PSSSTs in using SEPs, and how instruction is taken up by the PSSSTs and their students. The interviews were voluntary and a small stipend will be included for each

PSSST that participates. The manner in which data will be collected will be reviewed in the next section.

3.4.1 Data collection

The course work of Secondary Science Methods 1 will provide instruction to the PSSSTs concerning writing lesson plans. It is these lesson plans that will be analyzed for their incorporation of SEPs. Lesson plans will be examined five times during the semester from six of the PSSSTs in order to provide data to answer the research questions outlined above. The six PSSSTs whose lesson plans were to be analyzed and who were to be interviewed were randomly selected from the eleven PSSSTs in the Methods 1 course. Figure 3.1 shows all eleven of the PSSSTs (pseudonyms are used), including those who were randomly chosen for analysis of their lesson plans and selected for interviewing.

Randomly Selected PSSSTs

PSSST	Grade Level	Course
Kristine	**10**	**Conceptual Chemistry**
Kurt	**7 & 8**	**Physical Science**
Lisa	**9**	**Academic Biology**
Alexis	**10**	**AP Chemistry**
Jennifer	**7 & 8**	**Physical Science**
Robert	**Not Noted**	**Chemistry**
Pat	9	Academic Biology
Stacy	10	Chemistry 1
Brandi	9 - 12	Conceptual Physics
Anne	7 & 8	Physical Science
Nikki	9	Biology 1

Figure 3.1. All eleven PSSSTs enrolled in this study and those who were selected for lesson plan analysis and interviews (shown in blue and bold).

The placement of Secondary Science Methods 1 in the university program, the role lesson plans play in the course, and planned collection of the lesson plan data (coded here as LP for lesson plan and WP for weekly plan) for this study are all depicted in Figure 3.2. Interviews are also listed under lesson planning because the interviews are in reference to lesson planning. Each of the codes for the lesson plans will be described in detail later in this section.

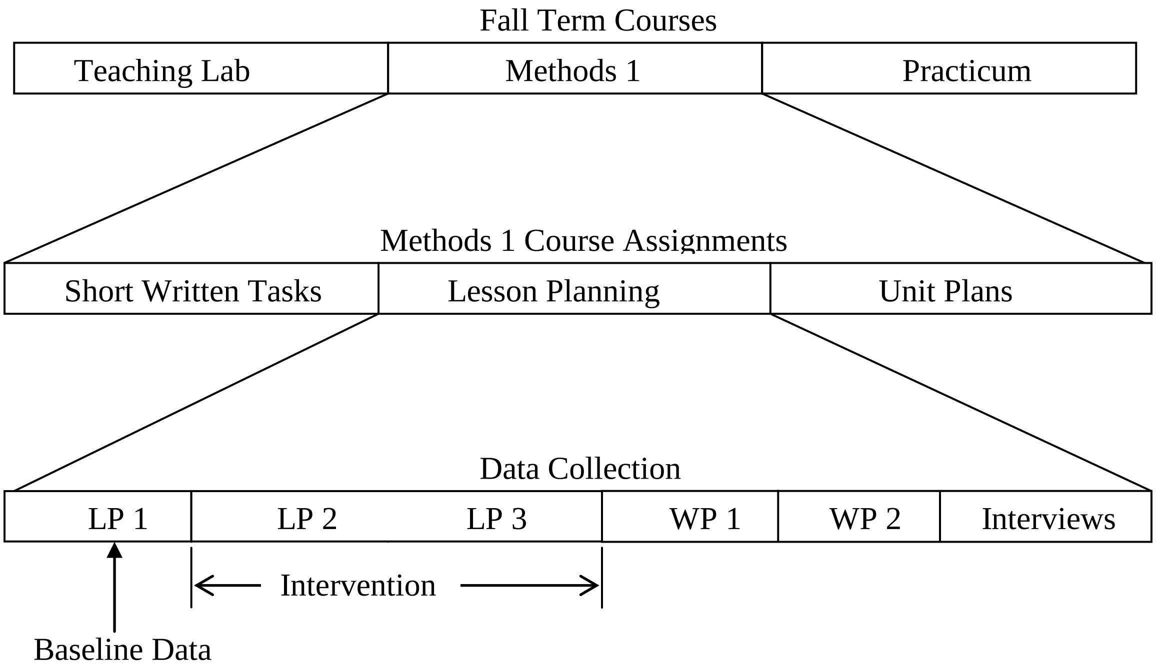

Figure 3.2. Data collection placement in the structure of the fall term of the MAT program. Lesson planning is coded here as LP lesson plan and WP for weekly plan. The grey shaded boxes indicate the intervention.

3.4.2 Lesson plans

PSSSTs are required to write lesson plans for the each lesson they enact during their internship and as part of their methods courses at the university. These lessons are completed electronically and uploaded to a server so that these documents can be viewed by the cooperating teacher, university supervisor, and the professor of the Secondary Science Methods 1 course. The lesson plans required for the university follow a particular template and the cooperating school district allows this template to serve as the daily lesson plan template for the school lesson plans.

Sharing a common lesson plan template will help to ensure that lessons that are examined for this study are very similar to lessons that the PSSSTs will be using in their classrooms because it would take too much time for the PSSSTs to write an entirely separate lesson plan for a given lesson.

The first lesson plan (LP 1) will be collected between the first and second week of the Secondary Science Methods 1 course. This lesson plan will serve as the baseline measure of the PSSSTs' ability to incorporate the SEPs into their planning of lessons.

The first class meeting will describe research concerning students as learners and adolescent development. In addition, the PSSSTs will read Chapter 3 of the NRC's (2012) *Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas,* which formally introduces the SEPs. It is after reading this chapter that the PSSSTs will write their baseline lesson plan (LP 1). This baseline lesson plan will answer the first research question, which asks how reading about the SEPs influences PSSSTs' lesson planning practices. While causality cannot be known, the baseline data will show what the PSSSTs do after the reading.

The topic(s) for each PSSSTs lesson plan that are turned into for the Secondary Science Methods 1 course for evaluation are selected by the PSSSTs. This allows the PSSSTs to write a lesson on content that is most familiar and they are most comfortable with, thereby allowing them to concentrate on incorporating SEPs. Because the PSSSTs are not burdened by working through new content, they are able to write plans that will most likely represent their best practice. It should be noted that while the topic of the lesson plans may be selected by the PSSSTs, there are constraints for each lesson plan. For lesson plan 1, there must be engagement in at least one of the science or engineering practice. Lesson plan 2 and lesson plan 3 must engage students in a portion of the learning cycle (either the *explore* and/or the *explain* portion) and the appropriate practices that occur during those parts of the learning cycle. The lesson plans that will be examined in November and December (called weekly plans) will be more typical lessons that the PSSSTs will be using in the classes that they are teaching, as opposed to theoretical lessons that may be written for a an assignment for the Secondary Science Methods 1 course.

The examined lesson plans will be analyzed for their incorporation and scaffolding of SEPs for their students by the PSSSTs. That is, are the SEPs present and are there strategies for helping students to overcome barriers to engaging in those practices. Each lesson plan will be read and evaluated using a SEPs coding scheme which will be described in a later section.

3.4.2.1 Intervention

This section will describe the intervention, which is the portion of the Secondary Science Methods 1 course that will represent the SEPs to the PSSSTs, decompose the SEPs for the PSSSTs, and allow for the PSSSTs to the approximate the SEPs. The intervention starts after the first class meeting of Secondary Science Methods 1 and continues through the third week in October. The overarching goal of the intervention is to help PSSSTs incorporate SEPs into their lesson planning practices. How the intervention proceeds will be discussed below.

(a) Workshop 1

The first portion of the intervention began during the first Saturday, all-day workshop and involved PSSSTs experiencing and engaging in SEPs. This was accomplished using Wisconsin Fast Plants, which are genetically engineered to complete a reproductive cycle (from seed to seed) in forty days. The PSSSTs worked with fully blooming flowering plants (planted 20 days before class) and were required to categorize taxonomically the features of the plants.

The PSSSTs shared their features with the class and the teacher prompted for operational definitions, revoiced students' statements, asked for elaboration, and modeled general scientific as well as teaching practices. The instructor used this session of the intervention and later parts in an effort to answer the questions of how Fast Plants grow.

The second activity involved the PSSSTs developing a measurement protocol for measuring particular growth features of the plants. After each group of PSSSTs produced a protocol, they were to have that protocol critiqued by another group. Here PSSSTs were engaged in authentic scientific work of constructing and critiquing each other's work. The instructor pushed the PSSSTs to clarify their meaning in a whole class discussion. The PSSSTs, under the guidance of the instructor, determined that clarity is about removing subjectivity, operationalizing definitions, quantifying measurements, and representing ideas using visual tools.

In the third activity, the PSSSTs enacted a protocol of measuring stem length and publically represented what they considered to be the typical stem length of each group's plants. The PSSSTs measured plants, transformed data into more usable forms, and selected representations that made their analysis visible. During discussions concerning the appropriate mathematical techniques, the instructor asked the PSSSTs how their students will react to this type of formalization of mathematical terms and how they will need to prepare learning experiences to meet the needs of their students.

The PSSSTs were then asked to reflect on their learning experiences and to think about how the work they completed compares with the work of scientists. The PSSSTs and the instructor agreed that the above activities are really about the planning and carrying out of investigations in an effort to construct explanations by analyzing and interpreting data, which are the three SEPs chosen for this study. The instructor then asked the PSSSTs to look at their baseline lesson plans (LP 1) and to think about how to revise them in a manner that would allow SEPs to be included. The instructor spent the rest of the workshop going through the formalities of writing lesson plans, getting into the nitty-gritty details of how to write as a professional educator.

The above describes the first portion of the intervention, including the baseline lesson plan (LP 1). Figure 3.3 provides an overview of the rest of the intervention, including the scaffolded instruction of the intervention and the data collected. Each of the items contained in Figure 3.3 will be described in greater detail later in this section.

The major point that was repeatedly brought to the forefront during the intervention workshops was that incorporating SEPs must be thoroughly planned for and they do not simply happen naturally during a classroom lesson. The SEPs were described in detail, with an example given for each practices as related to the experiences the PSSSTs engaged during the intervention. Classroom objectives for each SEP were referred to and each PSSSTs viewed the NRC’s (2012) Framework document during the discussion (which they received during the first class meeting). The PSSSTs were given time to review the descriptions of the SEPs and to ask questions concerning how the SEPs can be planned for during lessons. The PSSSTs were to formally write a lesson plans in the coming weeks that would be assessed in terms of incorporating SEPs.

	Intervention Instruction	Data Collected
Pre-Intervention	Read the NRC's *Framework*	
		Lesson plan 1 (LP 1)
Intervention	Workshop 1: Model engagement in scientific practices; talk about planning for these practices	
	Workshop 2: Model engagement, connect learning cycle organization to science practices	
		Lesson plan 2 (LP 2)
	Critical feedback from peer & instructor (about opportunities for students to engage in practices)	
	Workshop 3: Classroom discourse and norms	
		Lesson plan 3 (LP 3)
Post-Intervention		Week Plans 4 (WP 4)
		Week Plans 5 (WP 5)
		Interviews

Figure 3.3. The intervention consists of the workshops and critical feedback from the instructor and peers. The data collection is the form of lesson plans and interviews. The blue areas indicates the intervention phase of the study.

To summarize the intervention workshop 1, the PSSSTs contextualized how the SEPs could be incorporated in the PSSST's lesson plans by engaging in a model lessons that contains key aspects of the SEPs. The PSSSTs received detailed explanations that made explicit what SEPs are, what they look like when they are incorporated into lessons, and how they were planned for when designing the intervention.

The PSSSTs had a chance to modify their baseline lesson plan (LP 1) in an effort to incorporate SEPs into an existing lesson plan. The intervention continued two weeks later, when the SEPs were revisited as the PSSSTs learn to contextualize these practices with the educational practice of the learning cycle. This will be discussed in the next section, which describes workshop 2.

(b) Workshop 2

Workshop 2 focused on using the learning cycle to engage in SEPs. PSSSTs were introduced to the learning cycle while working with lunar data. The goal set for the PSSSTs was to attempt to find patterns in the data and communicate those patterns to the rest of the class. Once patterns emerged, the goal shifted to explaining those patterns and applying them to predict future events. The main point was that scientists argue from evidence and that students can also learn the same type of discourse.

During this workshop, explicit attention was given to determining which SEPs corresponded to which aspects of the learning cycle. For example, the *explore* portion of the learning cycle used the SEPs of asking questions, developing and using models, planning an carrying out investigations, using mathematical and computational thinking, and communication in the form of argumentation from evidence. This process of connecting aspects of the learning cycle to the SEPs was repeated for each portion of the learning cycle.

The instructor then engaged the class in an activity in which the PSSSTs needed to make claims about frog mutations in a rural area. Data consisting of biological pathogens and organic fertilizers were given. An important aspect of the lesson was to dissect the factors that made the activity challenging, both for secondary students and PSSSTs. The instructor then offered strategies to the PSSSTs for incorporating SEPs as a tool for not only engaging students in cognitively demanding tasks, but also for teaching science authentically.

PSSSTs were required to use what was learned during the second workshop and apply it to their next lesson plan. Lesson plan 2 (LP 2) had explicit directions to incorporate the *explore* or *explain* portion of the learning cycle into the lesson plan. These lesson plans were examined to see if SEPs were incorporated into the learning cycle lesson plans. Regardless of the outcome, PSSSTs were assigned another PSSST's lesson plan (LP 2) so as to critique those plans. This critique challenged the PSSSTs to determine if SEPs were present in the lesson plan and needed to offer suggestions where such practices could be inserted into the lesson plan.

The idea of critiquing as a means of engaging in scientific practice has been reported by Ford (2006), who states that to critique requires an understanding of how to construct. The complementing construction and critique of scientific knowledge is what Ford describes as having a 'grasp of practice' and is an attribute of scientific thinking. Therefore, critiquing a lesson plan is equivalent to modifying a lesson plan, which is often the case for PSSSTs who receive artifacts (lessons) from their cooperating teachers. Workshop 3 will complete the intervention and will be described in the next section.

(c) Workshop 3

Workshop 3 provided the last portion of the intervention, concentrating on scientific discourse and norms. The PSSSTs wrote their third lesson plan (LP 3). This lesson plan was critiqued by their peers in a similar fashion as described in the workshop 2 section above. During the entire intervention, the instructor and this researcher provided support to the PSSSTs as they worked through the tasks by offering suggestions, explaining what the incorporation of SEPs might look like in a secondary classroom, and citing examples of successful lessons that incorporate SEPs.

Lesson plan 3 (LP 3) was due in October and measured the PSSSTs' ability to incorporate SEPs while receiving the intervention instruction. The intervention instruction was mainly focused on the during the workshop meetings, which occurred on Saturdays in September and October, however, regular class meetings also supported the development of SEPs among the PSSSTs. (Note: Workshop is the term used on the syllabus to designate an eight-hour long class as opposed to a three hour evening class.) The intervention stretches across several class sessions during the first few weeks of the course term and includes reading of the NRC's (2012) Framework, engaging in scaffolded science practices in conjunction with the learning cycle, and receiving critical feedback from the instructor and peers.

3.4.2.2 Post intervention

The data collected from early September through the end of October was used to answer the second research question, which asks how successful the PSSSTs are at incorporating SEPs into their lesson planning during and after the intervention. To answer the third research question concerning the longevity of the instructional intervention on PSSSTs ability to incorporate SEPs when instructions to do so are no longer given and the PSSSTs are no longer graded on these SEPs, the six PSSSTs randomly selected were subsequently followed for the next two months (November and December) using the lesson planner tool online. The rationale for selecting six PSSSTs was to allow the researcher to view two PSSSTs' lesson plans for SEPs for a week in both November (WP 4) and December (WP 5). Each week, a different pair of PSSSTs from the six was selected for analysis. The decision for selecting six weekly lesson plans for each month in November and December was also predicated on weeklong holidays in each month and therefore only three of the four weeks for each month would yield analyzable data. The selection of weekly plans attempted to follow the same pattern in December as in November, meaning that the PSSST's weekly plan that was selected during the first week of November was also selected for during the first week of December. The second PSSST's weekly plan that was selected during the second week of November was also selected for during the second week of December, and so on.

The rationale for viewing PSSSTs' lesson plans for a week (WP 4 & WP 5) is that PSSSTs must work within the confines of the school district and the cooperating teachers' schedule. Examining a week of planned instruction will yield a fuller representation of what PSSSTs' capabilities are in incorporating SEPs by allowing for days in which the PSSST may need to follow their cooperating teachers plans, dealing with an overwhelming night class that may inhibit their best planning, choosing a lesson that contains content materials that happens to be antithetical to SEPs, or if the PSSST is simply having a bad day. Choosing two PSSSTs' lesson plans per week allows the researcher to analyze two lesson plans a day and analyze six teachers for two months after the intervention instruction. The extra week in November and December will be left for the holiday vacation days in which school is out of session.

Figure 3.4 depicts lesson plans that were analyzed from the six randomly selected PSSSTs in this study and also shows when those lesson plans were collected during the fall term. The codes for the lesson plans range from lesson plan 1 (LP 1) to lesson plan 3 (LP 3) and also include weekly plan 4 (WP 4) and weekly plan 5 (WP5). However, for the purpose of this study, writing, modifying, and critiquing of lesson plans are all valuable for determining PSSSTs ability to incorporate SEPs and they will be analyzed as equivalent data.

	PSSST	1	2	3	4	5	6	7	8	9	10	11
September	Week 1											
	Week 2		LP 1	LP 1	LP 1			LP 1	LP 1	LP 1		
	Week 3											
	Week 4		LP 2	LP 2	LP 2			LP 2	LP 2	LP 2		
October	Week 1											
	Week 2		LP 3	LP 3	LP 3			LP 3	LP 3	LP 3		
	Week 3											
	Week 4											
November	Week 1		WP4					WP4				
	Week 2			WP4					WP4			
	Week 3				WP4					WP4		
	Week 4											
December	Week 1		WP5					WP5				
	Week 2			WP5					WP5			
	Week 3				WP5					WP5		
	Week 4	I	N	T	E	R	V	I	E	W	S	

Figure 3.4. Six of the eleven PSSSTs will have their lesson plans analyzed and will be interviewed.

This study aimed to analyze a total of 78 lesson plans, representing six randomly selected PSSSTs from the original 11 PSSSTs. It should be again noted that a weekly plan is five days and is reflected in the Figure 3.4 as WP 4 or WP 5 (one week is five lesson plans).

The actual number of lesson plans analyzed was lower than what was planned. The reasons for this vary from corrupted files online, to encrypted codes of specialized software that were not available to this researcher, to files being lost or deleted. When electronic files were not available, the primary researcher made every attempt to acquire hard copies of the documents. This process of tracking down documents and attempting to acquire them was arduous but successful. Of the 78 pre-intervention and intervention lesson plans to be analyzed, 76 plans were acquired. Some of the acquired plans appeared to be incomplete and attempts were made to determine if the plans were indeed incomplete and if so, attempts to retrieve the missing data were made by this researcher. When all attempts to gather the most complete, updated, or final versions of the plans was exhausted, they were analyzed.

In terms of weekly plans, of the 60 that were to be analyzed, only 46 plans were analyzed. This was due the odd schedules of the cooperating school districts, where several days were filled with mandatory whole school test remediation, fieldtrips, speakers, special events days, and other programs that were beyond the control of the PSSSTs. In addition, some PSSSTs simply did not complete a lesson plan for a given day, or if it was written, it was not available to this researcher. For these reasons, an average week was closer to four lesson plans than five for each PSSST. The next section will describe the coding of the lesson plans that were analyzed.

3.5 CODING

The NRC (2012) has provided a framework of important SEPs that should be incorporated into classroom science lessons. Of the eight major categories of SEPs, three were chosen as applicable to this study: *planning and carrying out investigations* (SEP 3), *analyzing and interpreting data* (SEP 4), and *constructing explanations and designing solutions* (SEP 6). These three SEPs have been subdivided into manageable objectives by the NRC (2012) and are shown in Figure 3.4, Figure 3.5, and Figure 3.6. Check marks in the figures are examples of how an evaluation sheet might appear after critiquing a PSSST's lesson plan. The manner in which the lesson plans will be coded will be described in the next section.

3.5.1 SEP Coding

Coding for the SEPs was completed using the template as shown in Figures 3.5, 3.6, and 3.7, which lists the SEPs and the sub-SEPs detailed by the NRC (2012). The core SEPs are divided into sub-SEPs that can be checked against PSSSTs' lesson plans. If a single performance of a sub-SEPs is planned in the PSSSTs' lesson plan, then the core practice is marked present.

The process for coding lesson plans was completed by marking each instance of a sub-SEPs on a printed lesson plan. If a sub-SEPs was met more than once, it was marked on the lesson plan but was only marked as being present once on the checklist, not the number of times it was present. The reason for not counting instances of the same sub-SEP is due to the nature of lesson plan writing, which often describes what is supposed to happen several times throughout the plan and may include several places in the plan where that same act appears in the description of the work that students will completing. In addition, supporting worksheets, homework, and presentations may all incorporate a single act of a sub-SEP. Therefore, a discrete measure of present or not present was used to determine if a sub-SEP was present in the lesson plan.

☑ Planning and Carrying Out Investigations

✓	Formulate a question that can be investigated within a scope of the classroom, school laboratory, or field with available resources and, when appropriate, frame hypothesis (that is, a possible explanation that predicts a particular and stable outcome) based on a model or theory.
	Decide what data are to be gathered, what tools are needed to do the gathering, and how measurements will be recorded.
	Decide how much data are needed to produce relievable measurement and consider any limitations on the precision of the data.
	Plan experimental or field-research procedures, identifying relevant independent and dependent variables and, when appropriate, the need for controls.
	Consider possible confounding variables or effects and ensure that the investigator's design has controlled for them.

Figure 3.5. SEP 3 and its sub-SEPs.

☑ Analyzing and Interpreting Data

	Analyze data systematically, either to look for salient patterns or to test whether data are consistent with an initial hypothesis.
	Recognize when data are in conflict with expectations and consider what revisions in the initial model are needed.
	Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information and computer technology to collate, summarize, and display data and to explore relationships between variables, especially those representing input and output
✓	Evaluate the strength of a conclusion that can be inferred from any data set, using appropriate grade-level mathematical and statistical techniques.
	Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlation relationships.
	Collect data from physical models and analyze the performance of a design under a range of conditions.

Figure 3.6. SEP 4 and its sub-SEPs.

☑ Constructing Explanations and Designing Solutions

	Construct their own explanations of phenomena using their knowledge of accepted scientific theory and linking it to models and evidence.
✓	Using primary or secondary scientific evidence and models to support or refute an explanatory account of a phenomenon.
	Offer causal explanations appropriate to their level of scientific knowledge.
✓	Identify gaps or weaknesses in explanatory accounts (their own or those of others).
	Solve design problems by appropriately applying their scientific knowledge.
	Undertake design projects, engaging in all steps of the design cycle and producing a plan that meets specific design criteria.
	Construct a device or implement a design solution.
	Evaluate and critique competing design solutions based on jointly developed and agreed-on design criteria

Figure 3.7. SEP 6 and its sub-SEPs.

Analyzed lesson plans were entered into a spreadsheet program that listed each sub-SEP and the particular assignment for each PSSST. A “Y” was entered for the sub-SEP for that assignment if it occurred at least once in the lesson plan. An “N” was entered if the sub-SEP was absent or had not met the full criteria of the sub-SEP. Figure 3.8 displays template for the coding process and contains the data for lesson plan 1, which will be analyzed in the next chapter.

LP1 - 9/8/2013		3A	3B	3C	3D	3E	4A	4B	4C	4D	4E	4F	6A	6B	6C	6D	6E	6F	6G	6H
PSSST Number	Course Examined	3 A	3 B	3 C	3 D	3 E	4 A	4 B	4 C	4 D	4 E	4 F	6 A	6 B	6 C	6 D	6 E	6 F	6 G	6 H
Kristine	Conceptual Chem Period 5	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Kurt	Physical Science 7/8	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Lisa	Academic Biology Per. 1	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Alexis	AP Chemistry	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N
Jennifer	Physical Science 7/8	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Robert	Chem 1 CAS Per. 7	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N
	Total Sub-SEPs	1	0	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0

Figure 3.8. Spreadsheet template and data for lesson plan 1.

Inter-rater reliability was determined by comparing the number of agreements for each sub-SEP between the primary researcher and the second coder by the total number of possible sub-SEP for each lesson plan. The second coder was chosen because she is a secondary science teacher who has taught both junior and high school science and is a graduate of the MAT science program.

The SEP and the sub-SEPs (displayed in Figures 3.5, 3.6, and 3.7) are filled with conjunctive statements that needed to be met in order to assign a particular sub-SEP for an act in a lesson plan. During training, discrepancies that arose between the primary coder and the second coder were resolved by invoking the supporting text of the New Standards Framework (NRC, 2012). When further questions arose, the supporting studies and documents that the New Standards Framework referenced were used to help gain context of the sub-SEP. This led to a set of coding statements that were written by the primary coder to help the secondary coder maintain the spirit in which the SEP and the sub-SEP were written. These coding rules are included in Appendix A.

An example of the need for the coding rules can be illustrated with the following scenario. The teacher instructs the students, step by step to insert the observations about water, oil, and soapy water into a pre-made table. For each observation, the students are directed to place the observation into a particular square of the table. By the end of the activity, the students have a neat table that displays their data. The question becomes if sub-SEP 4C has been met. The appearance of the table itself is tempting to mark this as meeting sub-SEP 4C, however, with closer scrutiny of the sub-SEP 4C, which reads: "Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information and computer technology to collate, summarize, and display data and to explore relationships between variables, especially those representing input and output," the decision becomes more difficult. The coders examined the supporting documents of the lesson plan, the laboratory exercise, and the accompanying worksheet supplied by the teacher's lesson plan, and found no mention of any type of cognitive work done with or from the table.

The question between the coders was if the table the students were using constituted achievement of sub-SEP 4C. To help with this decision, The New Standards Framework book (NRC, 2012) and the supporting documents were elicited. All have a "spirit" based on inquiry (which has been written extensively and summarized authoritatively in the Inquiry book (NRC, 2000) accompanying the National Science Education Standards (NRC, 1996). This prompted the primary coder to make comments under the original sub-SEP 4C using asterisks: "*Do students transform the raw data in a meaningful fashion?" and "*Do the students find slopes of a line in order to find a relationship?" This was agreeable to the second coder who felt that these coding rules were appropriate and useful. (A complete set of the coding rules, written by the primary coder, are written under each sub-SEP, and are given in Appendix A.) When the training was completed, the formal coding for the lesson plans began.

An average interrater reliability was computed by adding the individual interrater reliability scores together and dividing by the number of total lessons that were double coded. For this research, 25% of pre-intervention and intervention lesson plans were double coded and 4 of the 12 weekly plans were double coded (33%), yielding a total interrater agreement of .94. It should be noted that PSSSTs' artifacts' will also be analyzed for SEPs and will be considered part of the PSSSTs' lesson planning.

The number of sub-SEP that are met for given SEP will be used as a measure of completeness of the practice. That is, a PSSST that has met four sub-SEPs has more completely incorporated the SEP than if they had met only one sub-SEP. This definition of completeness seems viable because of the interconnectedness of the sub-SEPs. By meeting one of the criteria for a sub-SEP allows for another related sub-SEP to be met by adding another important component of the SEP. For example, when comparing sub-practices 6A, 6B, and 6C, all require developing explanations using evidence, however if causation is determined by using canonical scientific knowledge appropriate to their content level, then sub-SEP 6C is met. If they link this to accepted scientific theory or models, then they can also meet sub-SEP 6A. If they base these explanations in primary or secondary evidence that can refute or support these accounts, then sub-SEP 6B will also be met. Of course not every lesson will incorporate all of these practices nor should it be expected, however, lessons that do incorporate all three have devoted more attention to that SEP and it is considered to be more complete.

The coding of the SEPs as well as the sub-SEPs will be recorded into a spreadsheet. The spreadsheet will have placement for each of the sub-SEPs for each of the PSSSTs' lesson plans. This means that for every lesson plan for every PSSST, there will be a record of the SEPs and the sub-SEP that are either present or absent. (See Figure 3.8 for an example of this spreadsheet containing PSSSTs data.)

Once lesson plans were coded, the spreadsheet program was be programmed to count the number of SEPs present, including the sub-SEPs, before and after the intervention. This allowed the analysis to reveal not only which of the SEPs have changed in frequency, but which particular sub-SEPs.

Having a record of which SEPs and sub-SEPs are present can provide a vital link in making connections between the intervention and the uptake of the PSSSTs. This information can then be triangulated with interview questions to ultimately determine the efficacy of the intervention.

In the next section, the complementary data of interviews with PSSSTs will be described.

3.5.2 Interviews

The coding of lesson plans of the PSSSTs provides information about which SEPs and sub-SEP are being planned, when SEPs and sub-SEP were being planned, and if the intervention influenced SEPs and sub-SEP incorporation. Interview data helps to provide complementary data about why SEPs and sub-SEP are either being incorporated or not incorporated into PSSSTs lesson plans.

Interviews were conducted using stimulated recall protocol in an effort to determine how PSSSTs' incorporation of SEPs and sub-SEP practices into the lesson plans was influenced by the intervention (see Lyle (2002) for a description of the benefits and diversity of stimulated recall). During the interviews, the PSSSTs were able to view their lesson plans produced for their regular daily instruction as well as their formal lesson plan for Secondary Science Methods 1. In addition, instructional supports from the intervention were also present, including worksheets, notes, PowerPoint slides, handouts, and rubrics, in an effort to stimulate the PSSSTs to recall the intervention and more importantly, to help them explicate their thinking about their planning for SEPs.

The naturalistic style interviews followed a responsive interviewing protocol developed by Rubin and Rubin (2005) in which interviews are structured in a manner similar to normal conversations. The characteristics of the responsive interviewing model are grounded in interpretive constructionist philosophy, in which the interviewee's perspective is respected and may influence the interviewer's questions. This flexibility allows the interviewer to pursue statements made by the interviewee that highlight their experience and understanding of the world in which they live and work (Rubin & Rubin, 2005). The overall goal of the interview in this study is to enlighten the more positivistic results by grounding the PSSSTs' experiences and thoughts about incorporating SEPs into their planning.

Each interview was conducted in a private room, with the longest taking 29 minutes and the shortest about 19 minutes. The interviewing protocol began with rapport building questions and worked toward more directed questions. Each question had a follow-up question and a probing question in an attempt to increase depth of the responses. (See Appendix A for the interview questions.) This is a characteristic of responsive interviewing – to obtain deep understanding rather than breadth.

Each interview was recorded using an audio computer program, converted to mp3 files, and were then transcribed as dictated by the IRB approved protocol. The transcriptions were completed by the primary researcher by typing as completely as possible the text of the conversation. The names of all of the pre-service secondary science teachers were removed from the transcript so as to uphold the anonymity agreement described in the IRB approved protocol. Because the analysis is not a fine grain linguistic type, pauses, inflection, pronunciation, and non-verbal gestures were not recorded unless it seemed particularly noteworthy, showed a change in disposition of the interviewee, or seemed to hold particular meaning. The idiosyncrasies of daily speech were also recorded only if they seemed especially noteworthy. Typical pauses, repeated words, mispronunciations, and restarts were transcribed, as accurately as could be represented using a comma and improper spelling. When the interviewee would speak at length about a topic that was not pertinent to the study at hand, (such as a problem with a landlord) the transcriber would make a declarative statement about the main point of that aspect of the conversation, and then begin transcribing the exact text when the interview routed back to the interview question. If the interviewer asked a question that was not a main question, a follow up question, or a probing question, it was transcribed. If the interviewer responded to a statement made by the interviewee, it was also transcribed.

The transcriptions from each interview were printed and the primary researcher began to form a tabular organizer that summarized the main ideas from each interviewee for each question. This allowed the long text to be broken into data units, which are blocks of information that are examined together (Rubin & Rubin, 2005). Each data unit was composed of the main idea from each interviewee for each question. The resulting table could then be used to determine patterns in the responses. The data units were necessarily distilled into particular ideas, and the original text was summarized as efficiently as possible by using exact quotes when they were succinct, paraphrasing when the idea was clearly made but was too bulky to quote, and simply summarized when too jumbled and long-winded to be useful. Often the interviewee would make a clear statement and expand up this idea without adding much substance to the original statement, or conversely give lengthy statements that were finally summarized at the end of the statement. Only the PSSSTs' intent and the content of the statements were included in the summary table.

The summary for each question was completed by reviewing the summaries of each of the six interviewees' responses to the question, the follow-up question, and the probing question, using the tabular organizer to search for themes. When themes emerged, the interviews were checked against the original transcripts, and summarized into a text in the results section. Each main question has a section of the results section and includes the ideas and themes from the follow-up question and the probing question. When it was relevant, the frequency among the six PSSSTs was given for a given sentiment. If only one PSSST's perspective was given, it was indicated as such.

The interviews provide an emic perspective (a normative account of the PSSSTs' standpoint) on the intervention, the educative supports that were provided during the intervention, and the PSSSTs' thoughts about the SEPs, their ability to incorporate them into lesson, and their utility in teaching science. The analysis not only counted specific responses, but also looked for contradictions in the PSSSTs' responses. Contradictions arise at places in which perspectives of the researcher and the PSSSTs are misaligned and it is at these junctures that important information concerning contexts, actions, and differing viewpoints provided useful insight that can be examined in finer detail. Contradictions could also be used to develop claims about the data. The resulting data was then analyzed and will be presented in the next chapter.

3.5.2.1 Initial Coding Categories Expected During the Interviewing

The interview data will be analyzed using grounded theory (Glaser & Strauss, 1967), which is theory building for a particular use. Here theory is substantive in its use, pertaining to particular contexts and uses rather than being "grand" (Merriam, 2001). Tentative claims (hypotheses) can emerge from categories and properties of the data and can then be subjected to agreement tests against the data.

Analyzing within this paradigm does not preclude having prior knowledge and beliefs about what might be found in the data. Research illuminating PSSSTs has been presented in the previous chapter. Therefore, it is reasonable to expect certain facets will be present in the data. Interview data may help to reveal PSSSTs' abilities, desires, constraints, and affordances for incorporating SEPs into their daily lessons. This is because teachers may reveal the answers directly by answering the interview questions or indirectly by revealing their beliefs, which Haney, Lumpe, Czerniak, & Egan (2002) state are valid predictors of classroom action.

Initial coding of PSSSTs' responses to the interview questions may include the teachers' beliefs about science content, science practices, and their views of the feasibility of incorporating SEPs into their daily lessons. It can reasonably be expected that teachers will answer the interview questions in a manner that will reveal their experiences in the classroom, involvement in scientific work, and their perspectives about teaching. As Crawford (2007) points out, the most critical factor influencing a prospective teachers' intentionality and abilities to teach reform science [inquiry] is the prospective teachers' complex set of personal beliefs about teaching and views of science, which are a strong predictor of actual practice.

The responses to the interview questions can be framed in terms of a teacher's overall cultural ecology of science education which Bencze, Bowen, and Alsop (2006) point out, teachers' personal philosophies correspond with their tendencies to control students' science knowledge building. Tsai (2002) provides a framework for categorizing teachers' perspectives of teaching science as traditional, process oriented, and constructivist. In essence, traditional means transferring knowledge from the teacher to the student. The process perspective is one based on using the scientific method and discovery learning. Constructivist perspective is about helping students construct knowledge. Categorizing PSSSTs' perspectives may offer clues to why particular aspects of the intervention were helpful or not to particular PSSSTs.

PSSSTs' experiences with scientific research experiences will also be coded if it is offered. These scientific experiences can have a profound effect on beginning teachers' views of scientific practices and school science. For example, Varelas, House, and Wenzel (2005) describe beginning science teachers' immersion into 10-week summer apprenticeships at authentic science labs. They found that the beginning teachers began to appreciate certain science practices, including the nonlinearity, messiness, and risk taking aspects of science. As the beginning teachers acted as scientists, they began to see science more authentically, including the interplay of theory and data, and how speech acts differ from typical speech. This shows that the beginning teachers were able to adopt practices of scientists, rather quickly albeit with some floundering. However, the beginning teachers did experience conflict between how these practices were different than the school setting. For example, they felt conflicted in using the science practices in school, where they had a tendency to want to make things clear for the students, by providing linear explanations, that had structure, and closure. While the beginning teachers adopted identities of scientists in the lab, they remained wary of the applicability of such authentic science in schools, citing time constraints and the ability to motivate students as potential barriers. By coding for experiences that PSSSTs have had in science, a pattern may emerge with those that incorporate SEPs, and those that do not.

An additional category for interviewing includes the PSSSTs' views about their own students' capacity to engage in SEPs. The reason for this category is that PSSSTs have conceptions about how learning should take place in the classroom and how it should be framed. Hutchison & Hammer (2009) describe that school students feel that learning is often framed in such a way that it is about giving the teacher correct answers, not making sense of the natural world. Here, student framing is about how students use knowledge, whether they adopt roles as constructors, if they make connections between concepts and natural phenomena, as well as the language they use.

Hutchison & Hammer (2009) make the case that activities that focus on correctness may be unproductively framing the work of students, not as scientists, but more of players of the typical school game. Therefore, a tension about achieving correctness exists. Incorrect answers and predictions may frame the activity productively, and may result in future correctness, while correct answers that are simply repeated or that are already known are not associated with productive disciplinary engagement.

To summarize, coding for teachers' beliefs of science, their experiences with scientific work, and their conceptions of the viability of incorporating SEPs may help to provide an answer to why the intervention has been successful or not.

4.0 RESULTS

The purpose of this study was to determine whether PSSSTs were able to plan lessons that incorporated SEPs before, during, and after an instructional intervention. The PSSSTs wrote pre-intervention lesson plans, called Lesson Plan 1 (LP1), before an instructional intervention. At that time, the instructor conveyed the importance of the New Standards Framework, citing the integration of scientific practices, content, and cross cutting concepts. In addition the instructor informed the PSSSTs that future state standards might be influenced by this document and that the SEPs would be important for future lesson planning.[2] The PSSSTs followed explicit instructions to write a lesson plan that included at least one SEP and that this lesson should be one that could be enacted in the future. During the second meeting of the Secondary Science Methods 1 course, which also began the intervention, the PSSSTs submitted their lesson plans. These lesson plans (LP1) served as baseline data to determine if PSSSTs could incorporate SEPs into their lesson planning prior to the intervention.

The PSSSTs wrote Lesson Plan 2 (LP2) and Lesson Plan 3 (LP 3) during the instructional intervention. The SEPs analyzed for this study are closely aligned with the learning cycle, which

[2] The New Standards Framework has since been adopted as the key framework for the Next Generation Science Standards (NGSS), which is actively managed by Achieve (a nonprofit education reform organization).

was a major component of the instructional intervention. The learning cycle consists of *Engaging* students with an investigable question, having the students *Explore* by designing experiments that yield data that can be transformed in order to reveal patterns, and providing opportunities for students to develop and critique explanations (the *Explain* phase). The three SEPs analyzed in the PSSSTs' lesson plans were: SEP 3 – *Planning and Carrying out Investigations*, SEP 4 – *Analyzing and Interpreting Data*, and SEP 6 – *Constructing Explanations*, which hereafter will be referred to as Planning, Analyzing, and Explanations.

The learning cycle is an apt tool for promoting the incorporation of SEPs in classroom lessons. When students engage, explore, and explain, they are asking questions, planning and carrying out investigations, analyzing and interpreting data, and ultimately constructing explanations. Figure 1.2 shows the overlay of the learning cycle and the SEPs.

A timeline detailing when data was collected from the PSSSTs and how that data fit into the Methods 1 course is shown in Figure 4.1. The PSSSTs submitted lesson plan 1 (LP1) before the instructional intervention began. The only support the PSSSTs received was instructions to read Chapter 3 of the New Standards Framework (NRC, 2012), which described the SEPs and their role in the New Standards Framework. The PSSSTs submitted LP 2 and LP 3 during the instructional intervention, when the PSSSTs were themselves engaging in activities that promoted the use of the learning cycle. Weekly plans 4 and 5 (WP4 and WP5) were collected after the intervention and when the Methods 1 course no longer required the PSSSTs to submit lesson plans that were to be graded.

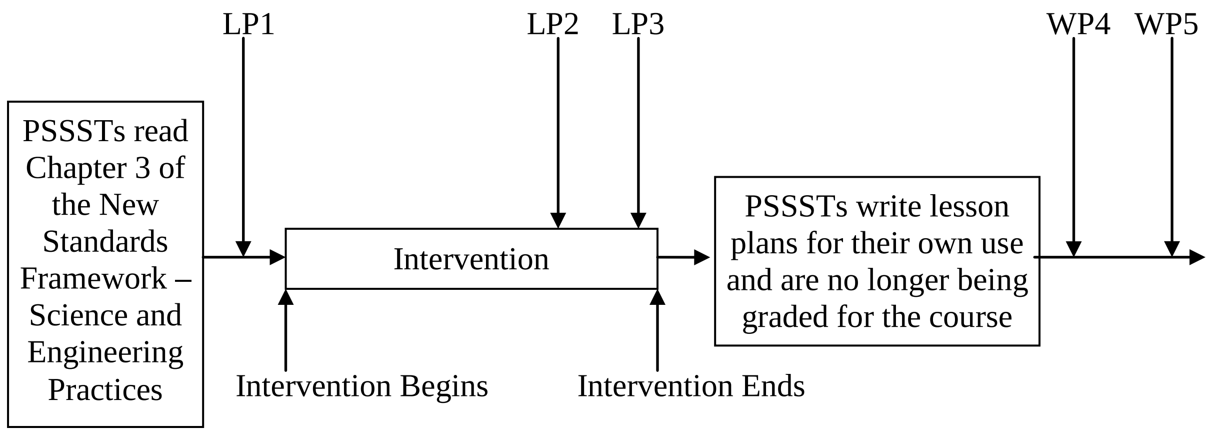

Figure 4.1. Timeline for the collection of lesson plans during the semester.

Section 4.1 will present the analysis of the PSSSTs' incorporation of the SEPs into their lesson plans before, during, and after the instructional intervention. Section 4.2 will describe the affordances or constraints that PSSSTs reported when planning for SEPs, as well as explore how these affordances and constraints influenced the incorporation of particular SEPs into PSSSTs lesson planning.

4.1 PSSSTS' INCORPORATION OF SEPS BEFORE, DURING, AND AFTER THE INSTRUCTIONAL INTERVENTION

This section will address whether PSSSTs were able to approximate the practice of incorporating SEPs into their lesson planning before, during, and after an instructional intervention. Coding entailed checking the PSSSTs' lesson plans for SEPs. If any sub-SEPs were present in the lesson plan, that plan was coded as containing that SEP.

Analysis of the LP1 data revealed that three of the six randomly selected PSSSTs (50%) incorporated SEPs into their lesson plans when they were given the SEPs (chapter 3 of the

NRC's New Standards Framework) and told that they were not only important, but were part of the New Standards Framework that would potentially influence future standards. Once the instructional intervention began, the PSSSTs wrote LP2. The analysis of LP2 shows that all of the PSSSTs were able to incorporate at least one SEP into their lesson plan immediately following the first instructional intervention meeting. The next assignment was LP3, where 4 of the 6 PSSSTs (67%) included at least on SEP into their lesson plan.

The significance of these results is that the PSSSTs demonstrated that some can approximate the practice of incorporating SEPs into their lesson plan, even without an instructional intervention. In sharp contrast, all of the PSSSTs approximated the practice of incorporating SEPs into their lesson planning for LP 2 when they were explicitly told to do so, and when they received instructional support in the form of an intervention.

The instructional intervention ended after LP3, but the PSSSTs were obligated to continue writing lesson plans for their cooperating teachers and their daily classroom instruction. These plans were not handed in for a grade and were no longer required by the Methods 1 course. Therefore, it would be reasonable to expect the SEP rate to return to the pre-intervention levels unless the PSSSTs adopted the lessons learned during the instructional intervention. Surprisingly, 83% of the PSSSTs incorporated SEPs into their lessons after the instructional intervention. These values were significantly higher than pre-intervention levels and were consistent with those of LP2 and LP3. Figure 4.2 shows the percentages of PSSSTs that incorporated SEPs into their planning for LP1, LP2, LP3, WP4, and WP5.

This analysis demonstrates that some PSSSTs were able to incorporate SEPs into their lesson planning before formal instruction was given, thereby approximating the practice. The data also demonstrates that this value dramatically increased once instructional support was given. Most surprising was that the PSSSTs continued incorporating SEPs after the instructional support was removed.

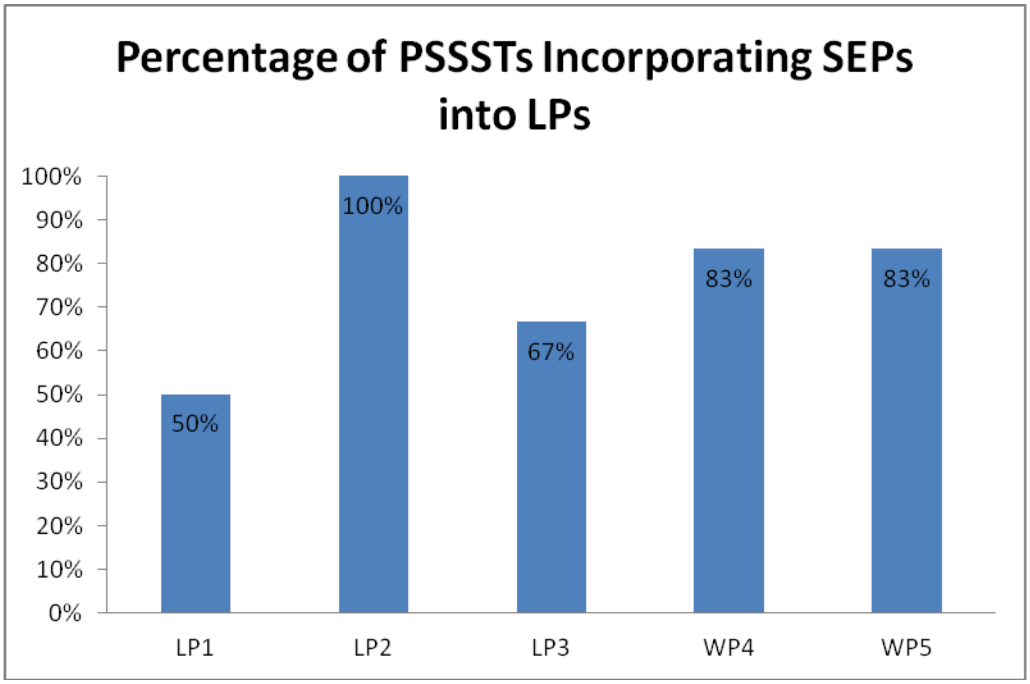

Figure 4.2. Percentage of PSSSTs using SEPs before (LP1), during (LP2 and LP3), and after (WP1 and WP2) the intervention.

Figure 4.3 provides a finer-grained analysis, which displays the number of sub-SEPs that were incorporated into LP1, LP2, and LP3 for all six PSSSTs. Again, the lesson plans were coded by marking the sub-SEPs as shown in Figures 3.5, 3.6, and 3.7. If a sub-SEP was present, then the lesson plan was marked as meeting the necessary criteria as containing that SEP. Lesson plans that contained more than a single SEP or multiple sub-SEPs from a single SEP were considered to be complete. Figure 4.3 displays the number of SEPs and sub-SEPs for each of the 6 PSSSTs for LP1, LP2, LP3, WP4 and WP5.

For example, PSSST Kurt did not incorporate a single SEP into LP1, but included one sub-SEP into LP2, and three sub-SEPs into LP3. Therefore, Kurt robustly incorporated SEPs into LP3, but not into LP1 or LP2. In addition, LP3 contained two different SEPs (two were SEP 4 -

Analyzing and Interpreting Data and one SEP 6 – *Constructing Explanations and Designing Solutions*). This is significant because meeting the criteria for a particular SEP increased the chances that a related sub-SEP would be met, but not for meeting a different SEP. For example, if Kristine was working on a lesson in which her students were to develop explanations, the lesson plan may meet the criteria of a second sub-SEP for explanations depending on the breadth of the lesson. It would be more difficult to meet the criteria for a different SEP, such as analyzing and interpreting data because that would require a discretely different aspect of scientific practice. It should also be noted that it is not always possible or appropriate to have multiple SEPs. A lesson that concentrates on explanations and does so completely may have greater impact than a lesson that attempts to also analyze and interpret data simultaneously.

Figure 4.3 shows that none of the LP1s' written by the PSSSTs contained two different SEPs, however there is one LP2 that incorporated two SEPs and three LP3s' that contained two SEPs. Therefore, the data appears to show that the completeness of SEP use among the PSSSTs increased with the instructional intervention.

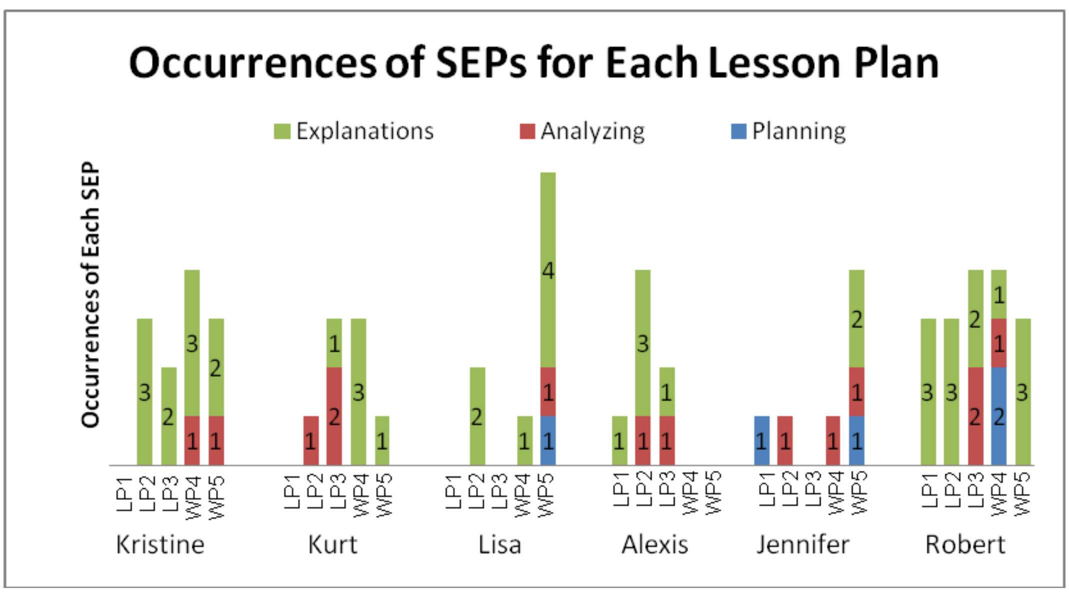

Figure 4.3. Occurrences of SEPs in PSSSTs' LP1, LP2, LP3, WP4, & WP5 for the six PSSSTs.

As described in Chapter 3, six of the eleven randomly selected PSSSTs had their weekly plans evaluated. The analysis of weekly plans 4 and 5 (WP4 and WP5) are also displayed in Figure 4.3. Here, a pattern of the diversity of SEP use becomes visible as PSSSTs move from LP1 through LP2 and LP3 and into WP4 and WP5. As noted before, none of the first lesson plans (LP1) have more than a single SEP represented, however, four of the six PSSSTs have at least two SEPs represented in WP4 and WP5 and three of the six have three SEPs represented in these weekly plans. This again shows that the majority of the PSSSTs become more complete in their incorporation of SEPs into their lesson planning. It again should be noted that the number of SEPs or sub-SEPs is not an accurate method for establishing the appropriateness for incorporating of SEPs, just that SEP and sub-SEPs are present.

The PSSSTs' lesson plans represent a variety of topics that were written for several different courses and grade levels. Figure 4.4 demonstrates the variety of grades, courses, and science content that were analyzed for LP1 and also lists which sub-SEPS were incorporated into LP1. LP 2, LP3, WP4, and WP5 had similar variation in the lessons and are available in Appendix C.

PSSST	Grade Level	Course	Lesson Name	Scientific Concepts	Sub-SEPs Included
Kristine	10	Chemistry	Moon Phases	Earth-Moon System	None
Kurt	7 & 8	Physical Science	Moon Phases	Earth-Moon System	None
Lisa	9	Biology	Mendelian Genetics	Dominant and Recessive Traits	None
Alexis	10	Chemistry	Water	Hydrogen Bonding	6B
Jennifer	7 & 8	Physics	Characteristics of a Good Test	Scientific Inquiry	3A
Robert	Not Noted	Not Noted	Behavior of Water at the Molecular Level	Molecular Interactions of Water	6A, 6B, 6C

Figure 4.4. The grade level, the course, and the scientific topics for each PSSST for LP1.

To give a sense of what these lesson plans contained, two lesson plans will be described. The first is LP1 from PSSST Alexis, who wrote a lesson that focused on the cohesive forces between liquid molecules. In her lesson plan, her students took notes, viewed a PowerPoint presentation, and engaged in a scripted laboratory exercise. The students were required to guess how many pennies would fit into a cup of water before it overflowed. The students then filled in a worksheet that contained a table where students placed their values from the experiment. The teacher prefilled the table headings and the students simply needed to write the number of pennies required for the cup of water to overflow. The students repeated this process using oil and soapy water. Figure 4.5 is a replica of this table.

		Water	Oil	Soapy Water
Number of Drops	Run 1			
	Run 2			
	Run 3			

Figure 4.5. A representation from PSSST Alexis's LP1.

The students were also required to draw a side view of the cup as it was about to overflow. The students placed drops of water, soapy water, and oil onto wax paper and were instructed to compare the shape of each drop. In the question section, two questions were written as follows: What does a high surface tension do to the number of liquid molecules that stay together? Based on your evidence, compare the surface tension of the three substances. This particular set of questions was coded as a 6B – *Using primary or secondary scientific evidence and models to support or refute an explanatory account of a phenomenon*. Here the students used the data that they had collected to help support their ideas of cohesion between opposite charges within the three different types of molecules. This particular lesson did not include SEP 3 –

Planning and Carrying-Out Investigations because the students did not plan any part of the activity. Simply carrying out a procedure itself also does not meet the criteria for any sub-SEPs. SEP 4 – *Analyzing and Interpreting Data* was also not present because the students simply put numbers into a pre-made table. They did not transform the data, systematically look for patterns in the data, explore the relationships between the variables, use any grade appropriate mathematics, nor distinguish between causal or correlation relationships. This lesson is an apt example of students engaging in a "hands-on" activity that had the potential to incorporate several SEPs and sub-SEPs.

In a similar lesson dealing with water, entitled, "Why is a Water Molecule Polar?", PSSST Stacy wrote LP1 to include using the periodic table, molecular models, and a table of electro-negativities (all in the form of handouts) to develop the students' ability to determine if molecules are polar or non-polar. The students were placed into competing groups and required to answer "Do Now" questions that were flashed onto the projector screen using PowerPoint slides. The students needed to conduct a theoretical investigation concerning particular molecules. This required the students to make claims about their particular molecule and attempt to convince other group members about their claim. The students used their evidence (which was secondary evidence given to them by the instructor) to back their claims. The students looked at the molecular geometry, the electronegativity of molecules, and the position on the periodic chart to make their case. In this lesson, students constructed their own explanations using scientific theory and models, used secondary evidence to support their claims, and offered causal explanations appropriate to their level of scientific knowledge. This met the criteria for sub-SEP 6A, 6B, and 6C (refer to Figure 3.7). It should be noted that Stacy is being used here for illustrative purposes and was not one of the randomly selected six PSSSTs used in this analysis.

PSSST Alexis then wrote LP2 which incorporated sub-SEP 4A (representing SEP 4 *Analyzing and Interpreting Data*) and sub-SEP 6A, 6B, 6C (representing SEP 6 – *Constructing Explanations*). This was a dramatic increase from LP1. Alexis' LP3 also included both SEP 4 and SEP 6, each representing one sub-SEP (4C and 6C). WP4 and WP 5 did not contain any SEPs for PSSST Alexis. Figure 4.6 displays Alexis' SEP usage (as well as the other five PSSSTs') and sub-SEP usage for LP1, LP2, LP3, WP4, and WP5. Aside from PSSST Alexis, all other PSSSTs analyzed increased either in the number of SEPs or sub-SEPs incorporated into their lesson planning from their original LP1 level.

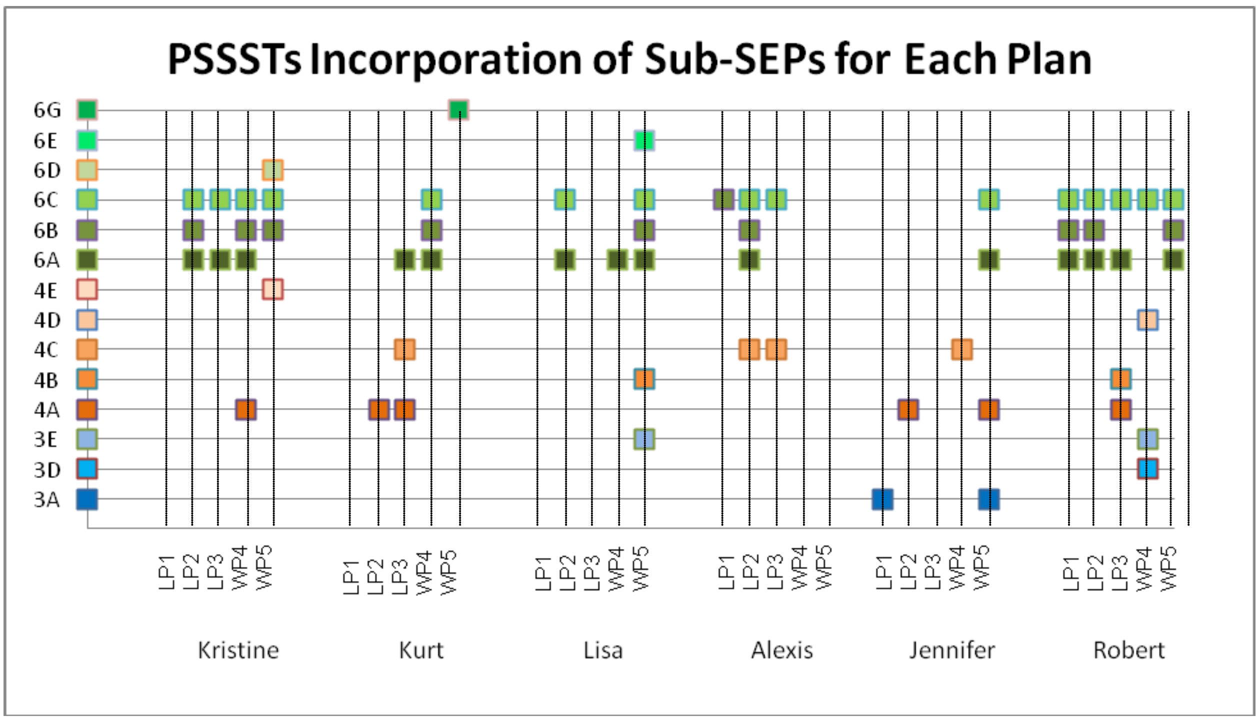

Figure 4.6. The PSSSTs Sub-SEPs Incorporation for LP1, LP2, LP3, WP4, and WP5.

What these results suggest is that some PSSSTs (50% in this study) can plan lessons to include SEPs with minimal support (reading a chapter of the New Standards Framework), but that rate dramatically increased with an instructional intervention. For example, the rate of incorporation of SEP usage by PSSSTs increased to 100% after the initial instructional intervention. What is more interesting is that the SEP usage became more complete (increasing the number of SEPs or sub-SEPs into lesson plans). The general trend for the PSSSTs in this study was to become more complete in terms of including SEPs into lesson plans (as shown in Figure 4.6).

For example, looking at the PSSST Kristine's data from Figure 4.6, she did not include any SEPs into her LP 1. Her LP1 dealt with the phases of the moon and her lesson plan was filled with information and content standards that she planned on delivering, but did not contain any SEPs. Kristine's LP 2 and LP3 then included SEP 6 – *Constructing Explanations*.

Kristine's LP2 had students investigate the physical and chemical changes in burning a candle. The students followed directions and collected data that the teacher intended the students to obtain. The students did not systematically analyze the data, but instead were instructed to construct explanations of the phenomena directly from their observations and to support their explanations using scientific knowledge and scientific theory, which in this case is kinetic molecular theory. This met the criteria for constructing explanations using data and linking it to scientific theory. In this lesson, Kristine's lesson planning incorporated three sub-SEPs of SEP 6 (6A, 6B, & 6C). Kristine's LP2 demonstrates completeness in her incorporation of SEP 6 in that she not only met one of the criteria for a sub-SEP, but three separate criteria (refer to Figure 3.7 for sub-SEPs).

In LP3, Kristine again incorporated SEP 6, with two separate sub-SEPs. This lesson was about atomic theory, but did not include any data for making explanations, and therefore, sub-SEP 6B was not met for this lesson. Kristine's lesson plan met sub-SEP 6A and 6B, again showing completeness for SEP 6. Kristine's LP 3 more completely incorporated SEP 6, but not as completely as her LP2.

Kristine's WP4 dealt with temperature, heat, and energy in the form of moving particles, the students were again required to form explanations (coded as 6A, 6B, and 6C), but also included systematically analyzed temperature data of mixtures in an effort to check their initial predictions. This additional code, 4A, was an entirely separate SEP and was the first time it was used by Kristine.

Kristine's WP5 centered on chemical bonding in everyday activities. Her students were led to believe that a mysterious event happened in her house and the students were to use the knowledge of bonding to solve a mystery. The students were to use evidence to support their claims about what they thought had happened. The students were to skeptically review the claims others had made and to support or refute those claims. This lesson was coded as containing sub-SEPs 4E, 6B, 6C, and 6D.

What is most interesting is that the number of SEPs actually increased for Kristine's WP4 and WP5 lesson plan, which both included two separate SEPs. WP4 included three sub-SEPs for SEP 6 – *Explanations* and one SEP 4 – *Analyzing Data*. WP 5 again included two separate SEPs with SEP 4 having one sub-SEP and SEP 6 having three sub-SEPs. Sub-SEP 4E and sub-SEP 6D were both met for the first time in WP5.

From the above analysis, Kristine's SEP use appeared to become more complete. Clearly she was able to approximate the practice of incorporating SEPs into her lesson planning. That is, Kristine incorporated more SEPs into lessons, while also becoming more complete in the use of each individual SEP (by incorporating multiple sub-SEPs for a given SEP and utilizing different sub-SEPs). This suggests that the diversity of SEP use increased for the PSSSTs not only during the intervention, but continued to increase after the intervention ended. This trend can be seen in Figures 4.2, 4.3 and 4.6, which clearly show that Kristine's pattern was not anomalous. The diversity and frequency of use of the SEPs and sub-SEPs clearly diversify during and after the intervention.

Kristine's case was one in which her initial lesson plan did not contain a single SEP, but she steadily increased both her SEP use and sub-SEP use in future lesson plans. Robert represents a different case, in which he demonstrated ability to approximate the practice by incorporating SEPs into his original lesson plan. For LP1, Robert met the criteria for sub-SEP 6A, 6B, and 6C. In Robert's LP 2, he continued to show competency in meeting SEP 6, again with three sub-SEPs being incorporated into his lesson planning. However, in LP3, Robert's lesson plan diversified and included SEP 4, which contained two sub-SEPs. Robert also appears to show growth after the instructional intervention, both increasing in SEP usage and sub-SEP usage. In Roberts's case, he initially showed completeness in SEP 6, but became complete in other SEPs after the instructional intervention.

Both Kristine's and Robert's SEP usage began with SEP 6, which is primarily about explanations. Later, both PSSSTs incorporated SEP 4, which is primarily concerned with *analyzing and interpreting data*. Robert eventually also incorporated SEP 3, which is about *planning and carrying out investigations*, into his lessons. This is an interesting pattern that seems to overlay the learning cycle learned during the instructional intervention. Here, the learning cycle (Engage, Explore, and Explain) overlays SEP 3 - *Planning*, SEP 4 – *Analyzing*, and SEP 6 – *Explaining* (see Figure 1.2). Of course there is not a one-to-one correspondence between any part of the cycle and the SEPs analyzed here; however there is clearly a fit of the SEPs around the stages of the learning cycle.

Both Kristine and Robert incorporate SEP 6 (explanations) into lessons first, and then SEP 4 (analyzing data). Robert then also incorporates SEP 3 (planning investigations). In these cases, the learning cycle appears to be implemented by the PSSSTs in the reverse order of the typical learning cycle. Figure 4.7 corroborates this, showing a pattern of dominance of SEP 6 in LP1, with SEP 4 becoming prevalent during LP2, and SEP 3 appearing with WP 4. This may indicate the PSSSTs are more fully implementing the components of the learning cycle that directly correspond with the SEPs. That is, SEP 6 - *Constructing Explanations*, does correspond with the Explain portion of the learning cycle. As other representations of practice appeared during the intervention, such as SEP 3 – *Planning and Carrying Out Investigations* and SEP 4 – *Analyzing and Interpreting Data*, the PSSSTs added this competency to what they were able to approximate as they engage in the learning cycle. As the PSSSTs added new competencies to their approximations of practice, they were able to include them in their lesson plans while keeping those they previously mastered. Figure 4.7, which displays the frequency and diversity of SEPs in the PSSSTs' lesson plans before, during, and after the intervention, shows that explanations (displayed in shades of green) dominate early in the semester and continue throughout the semester, all the while adding new SEPs.

Figure 4.7 also shows the number of unique sub-SEPs before, during, and after the instructional intervention. The total number of unique sub-SEPs begins at 4 for LP 1, increases to 5 for LP 2 and 6 for LP3, and then up to 9 for WP4 and finally 11 for WP5. This is almost a 3-fold increase in the diversity of sub-SEPs used by the PSSSTs.

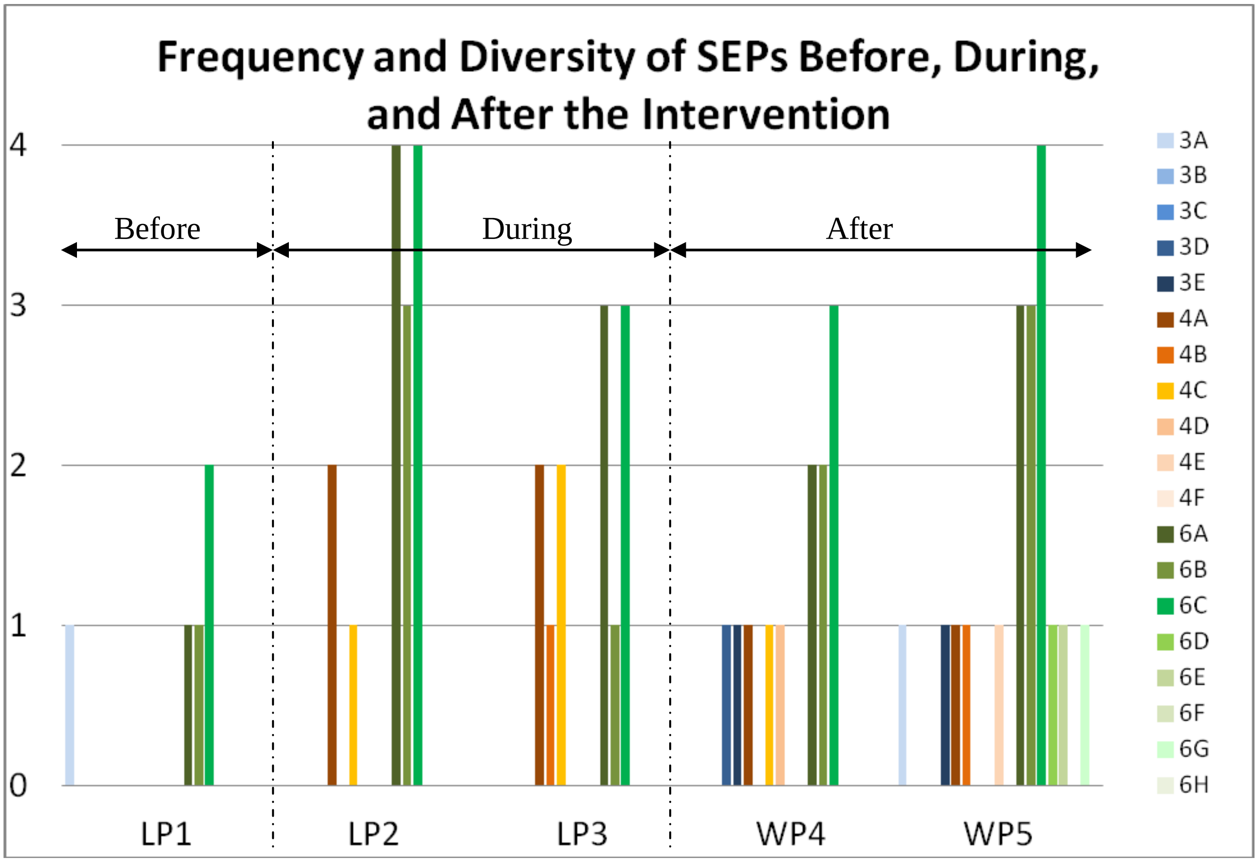

Figure 4.7. Frequency and diversity of SEPs before, during, and after the intervention.

The frequency of use of each sub-SEP also increases from a low of 5 for LP1 to 14 by LP2. Figures 4.8 shows the sub-SEP use for all of the lesson plans analyzed. LP 3 and WP4 both have 12 sub-SEPs and WP5 has 18 sub-SEPs. Figures 4.7 and 4.8 show an increase during and after the intervention of sub-SEPs usage.

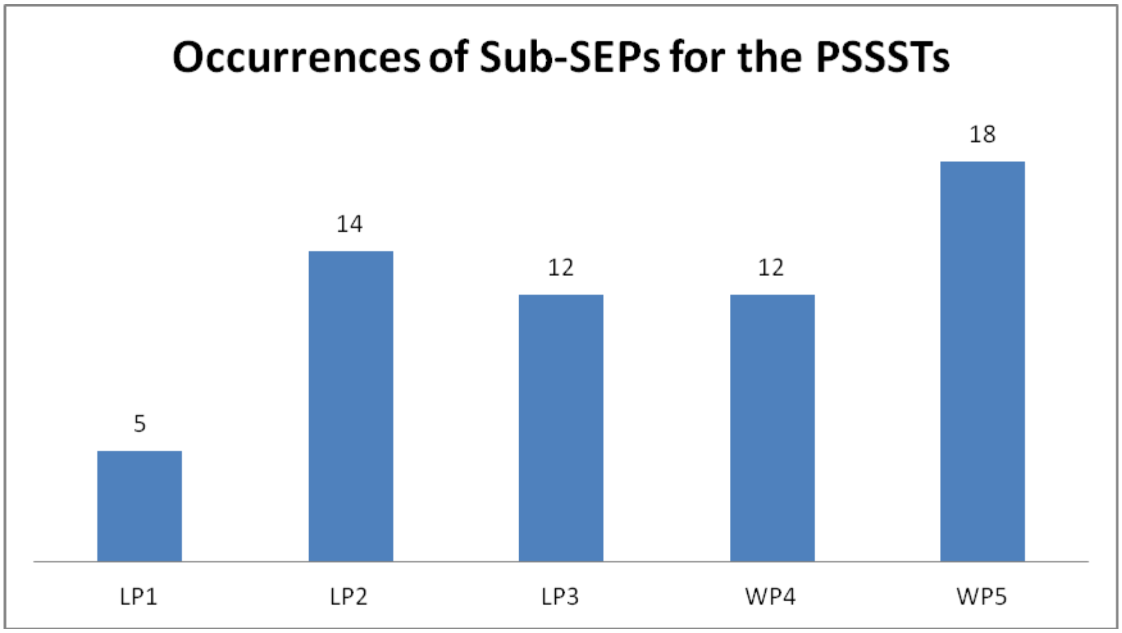

Figure 4.8. The number of occurrences of sub-SEPs for the PSSSTs.

Analyzing the PSSSTs' SEP incorporation reveals that SEP 6 - *Constructing Explanations* was approximately double the combined count for SEP 3 - *Planning and Carrying-out Investigations* and SEP 4 - *Analyzing and Interpreting Data* as shown in Figure 4.9. A potential reason for this discrepancy is that unlike planning and carrying out investigations (SEP 3) or analyzing and interpreting data (SEP 4), explanations are the "default option" of typical classroom practices (Cazden, 2001). That is, teachers play an authoritative role in classrooms, where teachers nominate students to provide a narrative, the teacher listens to the narrative, and then the teacher comments on the narrative. In science class, the narratives are often in the form of explanations.

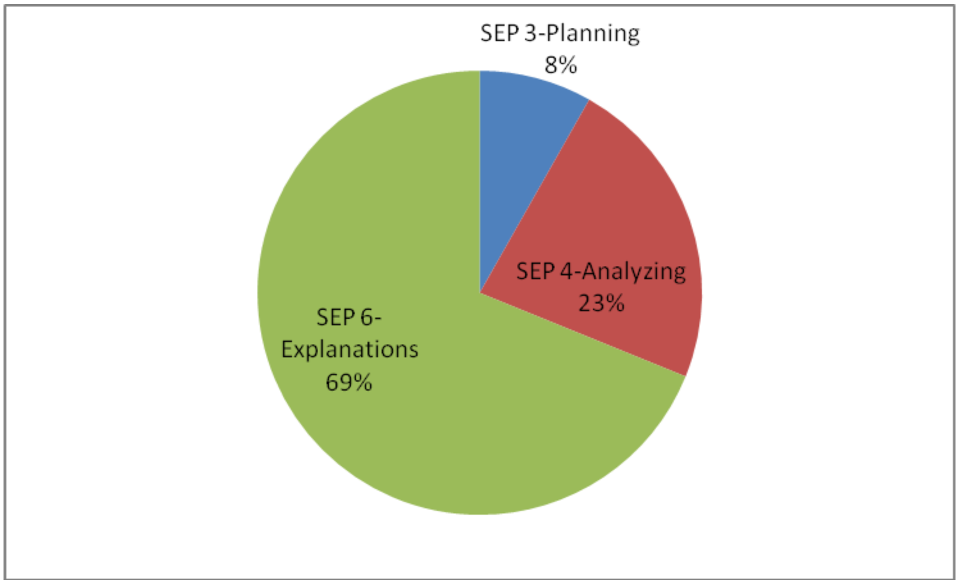

Figure 4.9. The overall occurrences of SEPs 3, 4, and 6 in PSSSTs' lesson plans.

Therefore, a typical classroom routine is one of teachers asking students to verbalize and/or write explanations using a typical pattern of question, answer, and evaluate also known as the "triadic dialogue" (Lemke, 1990). Here, the teacher asks students questions, students respond, and the teacher evaluates the response. This type of classroom discourse is ubiquitous in most classrooms, making up to 70% of classroom discourse (Wells, 1999), and can be structurally similar to forming typical classroom explanations. What characterizes a scientific explanation is the reliance of evidence, usually in the form of data, connected with scientific theories, models, and laws, which is often lacking in the initiate, respond, and evaluate (IRE) type of discourse.

To illustrate this claim, the sub-SEPs of SEP 6 (refer to Figure 3.7) are given in Figure 4.10, which shows that the sub-SEP 6A - *explanations linking models to evidence*, 6B - *using primary or secondary evidence to support or refute an explanatory account*, and 6C - *offering a causal explanations using appropriate scientific knowledge*, make up 93% of the explanations coded in the PSSSTs' lesson plans. These three sub-SEPs are most easily integrated into typical classroom practices because the common use of explanations can be modified to become more scientific explanations. This is in sharp contrast with planning and carrying out investigations, for which there is little precedent. It is uncommon for students to have agency in the development and enactment of scientific investigations in typical classrooms (Chinn & Malhotra 2002; NRC, 2005). It is, therefore, reasonable to expect planning and carrying out investigations to constitute a small percentage of the total SEP usage.

Figure 4.10 also shows that several of the practices that are considered more engineering like practices (solving design problems, constructing a device, or engaging in the design cycle) constitute a small or nonexistent portion of the sub-SEPs in this study. The engineering aspects of the SEPs were not a primary focus of the intervention and are not a typical occurrence in science classrooms.

An interesting note is also the absence of sub-SEP 6H which involves the critique of a design solution. While stated above, engineering aspects of the sub-SEPs were not a primary target of the intervention, the idea of critique is another scientific practice that is regularly absent in classrooms (Newton, Driver, and Osborne, 1999; Sadler, 2006).

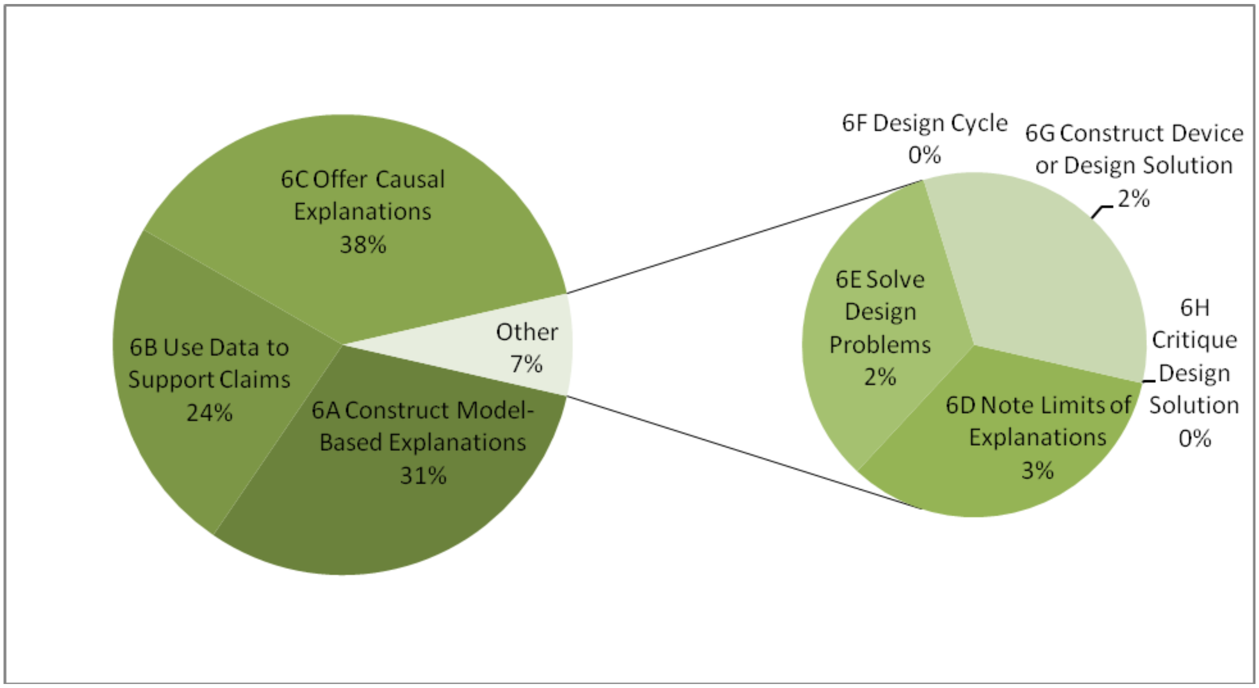

Figure 4.10. The sub-practices of SEP 6 for the analyzed lesson plans.

The quantitative analysis presented above is important for answering which SEPs and sub-SEPs are occurring and where they are occurring, however the qualitative analysis can help to explain why these results occur. The next section will explore the affordances and constraints that PSSSTs feel when planning lessons.

4.2 AFFORDANCES AND CONSTRAINTS FOR INCORPORATING SEPS INTO LESSON PLANS

This section will examine the affordances and constraints that PSSSTs feel when planning for incorporation of SEPs into their lessons. The six randomly selected PSSSTs that had their weekly plans analyzed, were also interviewed. These interviews were recorded, transcribed, and analyzed. Each of the interview questions targeted a slightly different aspect of the affordances and constraints for incorporating the SEPs into the lesson planning process. Subsection 4.2.1 will describe the rapport building questions of the interview, which will expose the PSSSTs' general demeanor and views on their teaching experience. Section 4.2.2 will focus on the unprompted aspects that PSSSTs feel are important for incorporating into daily lessons. Section 4.2.3 will explore the prospects of incorporating SEPs into daily lessons. Section 4.2.4 will discuss the potential for modifying current school artifacts to include SEPs. Section 4.2.5 will examine the intervention's effect on incorporating SEPs into lesson plans. Section 4.2.6 will explore how educative supports for SEPs were used by PSSSTs. Finally, section 4.2.7 will summarize the affordances and constraints that the PSSSTs feel when incorporating SEPs into their lessons.

4.2.1 Rapport building question

The interview started with a rapport building question, which helped to determine the overall experience of the PSSSTs. Five of the six PSSSTs answered the rapport building questions. The remaining PSSST did not answer this question due to a time constraint.

In general, the PSSSTs responded to the rapport building question of how everything was going at their placement with colloquial responses of “well” and “good.” However, when followed up with a question about how the students were responding to them, the PSSSTs had responses that indicated the very real stress of student teaching. The PSSSTs’ responses centered on authority in the classroom and their ability to manage and motivate students. Two of the five PSSSTs responded that the students see them as teachers, while two other PSSSTs complained that the students resisted their instructions. The final PSSST explained that she presents a strong authoritative stance with the students and they know there will be consequences for their actions.

Most of the PSSSTs expressed excitement and anxiety when questioned about the prospects of getting their own classroom. Robert’s comments seem to express the sentiments of being a student teacher and making the transition to the primary teacher role:

Robert:	I’m, I’m excited, but at the same time, it’s like, you know, I am, I’m glad, very glad that I have a second set of eyes in there…
Interviewer:	Parachute. Right…
Robert:	It’s like, if I am doing something and you know, and something is not done, he’ll swoop in, you know, and put away that chemical that I forgot to put away, and that kind of thing, so, there is definitely, yah, you know…
Interviewer:	Safety factor…
Robert:	Yah.

Robert Interview, 3:06 – 3:26

This seems consistent with previously reviewed research that finds that PSSSTs are primarily concerned with the logistical aspects of schooling (Brown & Melear, 2006). This is an important note, in that these PSSSTs are being asked to exhibit extraordinary teaching behaviors in incorporating the SEPs, but are revealing typical anxieties and thoughts of a new teacher. The next section will examine PSSSTs’ views of science.

4.2.2 Important aspects of science question

The first interview question elicited responses from the PSSSTs that exposed their notions concerning what aspects of science they felt were important for students to learn. The responses of the PSSSTs could then be compared with the SEPs and sub-SEPs to check for congruence. This type of information is important for understanding the PSSSTs' future responses concerning incorporation of SEPs in the lesson planning process, in that if SEP like responses were present and unprompted, then the PSSSTs were clearly thinking about the alignment of SEPs as an important instructional objective.

When formally asked what aspects of science were important for students to learn, the PSSSTs expressed a range of responses, including the importance of understanding everyday phenomena by thinking like scientists (both in terms of content knowledge and their practices). The content, according to the PSSSTs, seemed as a necessary base to understand how scientists arrive at knowledge and conversely, how scientists practice to develop content. In addition, the PSSSTs utilized key ideas of the epistemological aspects of science, ranging from understanding how research is conducted and how that research informs scientific knowledge, being appropriately skeptical, and backing claims with evidence. These responses indicate that the PSSSTs were not simply focused on content for their students, but held aspects of scientific practice as important. It is should also be noted that none of the PSSSTs naively mentioned anything about teaching using the "scientific method", but instead focused on key aspects of scientific work. Here is one example of a response from one of the PSSSTs:

> Kristine: Definitely to, uh…I,..I feel like such a rebel when I say this…but to challenge authority. Not, not so much just to challenge it, but to question evidence and the source… not take everything at face value, or you know, to accept what you're told. Actually question it and think about it. Because, I think a lot of my students sit there and listen to me and simply believe me and I want them to ask more questions and maybe challenge me more.

Interviewer:	So they will write anything down that you tell them and…
Kristine:	Yah, I think that is a big one…and I guess just sort of understanding the nature of research and that we don't know everything…
Interviewer:	Hmm…
Kristine:	…and that we're trying to figure out things, but there is kind of a way you do it, and not a scientific method, but just how research works and the limitations of it.

Kristine interview, 1:34 – 2:34

Another PSSST stated that:

Jennifer:	Being able to communicate the ideas effectively and also being able to back-up those ideas with evidence. Um, but that's for me personally. I know a lot of students will just give me an answer and I will tell them, why do you know that, why do you think that.
Interviewer:	Um-hmm, ok.
Jennifer:	It is what I feel is extremely important and…Just being able to also to actually, look at information, whether it is a science article or textbook, or trying to get information from reading that.

Jennifer interview, 3:17 - 3:50

These responses gave the impression that the PSSSTs held developed views of the nature of science and were not just concerned with acquiring content knowledge. They were interested in aspects that are vital to the scientific endeavor, including being skeptical, asking for evidence, learning how to engage with information, and avoiding dogmatism.

When followed up with a question concerning the importance of SEPs compared to content, there was unanimous agreement that both were important. However, qualifications were made. One PSSST explained that the grade level influences when one might be more important than another, such as teaching students scientific practices in middle school so that content could be focused on in high school. Another PSSST felt that the ability level of their students mattered, stating that honors students could handle SEPs because they understand the content. Yet another PSSST remarked:

Robert:	I mean, I think, not to say that content should be king, but I think content is king. And I think it is important that we incorporate as much of this into our content as we can…
Interviewer:	Those eight practices.
Robert:	Yah. And I think, sometimes it is a challenge for time, a challenge because how the students respond to our, um, implementation of some of these things.

Robert interview, 5:54 – 6:18

Robert's response foreshadowed three themes that the PSSSTs stated repeatedly during the interviews: that of feeling a push to cover content, the pressure to cover that content in a short period of time, and the resistance that students offer when deviating from typical school practices. Regardless, both content and SEPs, as one PSSST succinctly summarized, "go hand-in-hand" (Jennifer, interview, 4:15).

When asked to cite a particular example of how content and SEPs were utilized in their classrooms, the PSSSTs expressed that content and the need to cover content superseded the important SEPs aforementioned. Only two of the six PSSSTs gave specific examples that included an SEP. Both of these PSSSTs mentioned projects that concerned models, one for DNA and the other for molecular geometry. Neither developed models or revised a model, but appeared to only have used one sub-practice of modeling in the lesson. In addition to the molecular models, one of the PSSSTs had students develop a procedure for determining if bubbles made raisins rise to the top of a glass of soda.

The remaining PSSSTs offered other aspects they considered SEPs, but were not necessarily. These included drawing a Rube-Goldberg machine, discussing frictional forces, and learning content before completing a laboratory exercise. While it could be argued that an aspect or two of these activities might be considered a SEP if it was expanded further in a written lesson plan, the PSSSTs were free to give any idea, without corroborating evidence (lesson plans, pictures, or witnesses) and yet they were unable to embellish, during the interview, a laboratory activity or project that fit the definition of SEPs. This seems to indicate that the PSSSTs were either not entirely familiar with the SEPS or if they had familiarity with the SEPs, their ability to use those SEPs in the classroom remains underdeveloped. Again, this is consistent with previous research that shows the fragile nature of PSSSTs' knowledge of aspects of science beside content

(Lederman, 1992). Another possibility is that the PSSSTs hold a different understanding of the SEPs than those presented by the New Standards Framework.

The responses of the PSSSTs indicated that some may hold developed views of scientific practices (ex. mentioning models), but they may need more than just that knowledge to incorporate these practices into their daily lessons (as evidenced by their lack of specific examples of lessons that include SEPs). PSSSTs' responses about the viability of incorporation of SEPs into daily lessons will be examined in the next section.

4.2.3 Prospect of incorporating SEPs into daily lessons

When asked if SEPs were able to be incorporated into daily lessons, PSSST Kurt was optimistic, stating that all of the SEPs could be incorporated every single day. This response seemed to indicate that at least for this particular PSSST, it was not only possible, but reasonable to think that every SEP could, and maybe even should be in every lesson. Kurt's overly optimistic response seems unreasonable considering the difficulty of incorporating any particular sub-SEP. This may indicate that Kurt has not thought through the difficulty of incorporation of the SEPs. In viewing Kurt's lesson plan data, he was only once able to incorporate two SEPs into a lesson, with a total of three sub-SEPs.

The rest of the PSSSTs interviewed stated that they thought it was possible, but were not as optimistic as the PSSST mentioned above. Most of the PSSSTs mentioned a particular SEP as an example of one that seemed reasonable for their classroom. One PSSST did not answer this question, but of the remaining five PSSSTs, 4 felt that some of the SEPs could be incorporated into daily lessons easier than others.

The particular SEPs that the PSSSTs felt possible to incorporate varied without a recognizable pattern. Figure 4.11 lists the SEPs that the PSSSTs explicitly stated were able to be incorporated into daily lessons. In addition, those SEPs mentioned in responses to other questions throughout the interview are in bold-italics. The average number of SEPs that PSSSTs stated when explicitly asked about the feasibility of incorporation into daily lessons was 2.5 SEPs. The average is 4.0 SEPs when the entire interview is included. This is significant in that the PSSSTs are demonstrating their knowledge of SEPs and their willingness to use SEPs when designing classroom lessons. That is, the PSSSTs were thinking in terms of SEPs when they were conversing about classroom lessons, even when not prompted to do so.

SEP	Kristine	Lisa	Kurt	Bobby	Alexis	Jennifer
1. Asking questions and defining problems			Y	Y		***Y***
2. Developing and using models	Y	Y	Y	***Y***	***Y***	
3. Planning and carrying out investigations	Y		Y		***Y***	
4. Analyzing and interpreting data		Y	Y	Y		***Y***
5. Using Mathematics and computational thinking	Y		Y		***Y***	
6. Constructing explanations and designing solutions		Y	Y	***Y***	***Y***	Y
7. Engaging in argument from evidence	Y	***Y***	Y			***Y***
8. Obtaining, evaluating, and communicating information	Y	***Y***	Y			***Y***

Figure 4.11. SEPs that PSSSTs cited as possible practices that could be incorporated into daily lessons. Bold/italicized values indicate that practices mentioned without an explicit prompt in the interview.

When asked what might impede incorporation of SEPs into daily lessons, the responses centered on the amount of time needed to incorporate SEPs into lessons (both planning for and enacting these lessons) and the tension this time constraint would have with the current curriculum that pushes content coverage. Additional responses included the resistance they expected from the students. Only one PSSST mentioned that the ability of the teacher might be a factor for incorporation of SEPs into daily lesson plans. The significance of this is that PSSSTs that have inflated self-efficacy may not see the need to improve upon their current practice and may resist learning how to teach science further (Settlage, Southerland, Smith, and Ceglie, 2008; Wallace, 2013) Most of the PSSSTs in this study responded with answers involving external constraints with only one mentioning an internal constraint. This could indicate that the PSSSTs have not considered that their ability to teach in a classroom may be in need of improvement. However, as indicated in the rapport building question, the PSSSTs seem well aware of the difficulty in managing a science classroom.

When asked if they had attempted to incorporate SEPs into lessons other than those required for a course, the unanimous response was affirmative. However, when the PSSSTs expanded upon their initial responses, they provided little detail. It was therefore difficult to assess if their lessons would meet the definition of the SEPs as defined by the NRC (2012). The PSSSTs' perceptions could not be coded without corroborating written lesson plans to analyze.

Of the six PSSSTs interviewed, only three mentioned any details about those lessons that might have contained SEPs. For example, one PSSST described using a computer simulation in which climbers were required to acclimate as they ascended a mountain. The students were required to calculate when they (climbers) needed a break from climbing. The students were also required to explain why they took a break. This lesson definitely has the potential to use the SEPs, but could also require simple calculations and repeating a canned response. Again this suggests that the PSSSTs might not have a fully developed understanding of the SEPs. Alternatively, the PSSSTs may have a solid understanding of the SEPs, but not how to apply the SEPs in classroom lessons.

Other responses were much more ambiguous. For example, one PSSST stated that she was always asking questions, and therefore students would need to answer. If they did so, they needed to give evidence, thereby meeting SEP 1 - *Asking Questions and Defining Problems*, SEP 6 - *Explanations,* and SEP 7 - *Engaging in Argument from Evidence*. Again, asking students questions certainly has the potential for incorporation of SEPs, but is no guarantee. Research described in chapter 2 (Lemke, 1990; Mehan, 1979; Wells, 1999) demonstrates that the vast majority of classroom dialogue is monologic and usually follows a pattern of reciting known answer responses.

To summarize, most of the PSSSTs felt that it was at least theoretically possible to incorporate SEPs into daily lessons, but was dependent on the discipline, the time they were able to devote to classroom enactment and planning, and the willingness of students to participate. Most of the PSSSTs felt that they had incorporated SEPs into their lessons, however, the descriptions they offered were not clear enough to determine if they had in fact done so. The reasons that PSSSTs cited for not incorporating SEPs into lessons were all external, with only one PSSST mentioning that her ability may have played a factor.

In the next section, PSSSTs' responses about modifying current school lessons to include SEPs will be reported.

4.2.4 Modifying current school artifacts to include SEPs

The next question posed to the PSSSTs centered on modifying current school artifacts to incorporate SEPs into classroom lessons. In response to the question if typical laboratory exercises were able to be adapted to include SEPs, the PSSSTs all seemed optimistic. The PSSSTs stated that if teachers devoted classroom time that promoted student work in developing procedures, in analyzing data, and in developing conclusions, as learned in their MAT courses, they could draw on existing procedural type laboratory exercises to include SEPs. Two of the six PSSSTs used the term “cookie cutter” and another used the term “recipe-based” to describe the typical laboratory exercises that they encounter with their curricula.

Although the PSSSTs seemed optimistic about incorporating SEPs, one PSSST stated her school banned labs completely due to student behavioral problems. Another PSSST stated that using the SEPs is, “how you plan lessons.” This enthusiastic PSSST qualified this statement stating that this is a theoretical more than a practical statement. This quick response affirming the potential for incorporation of SEPs and then quickly hedging that claim seemed to be a reoccurring theme for the PSSSTs. This seems to indicate a desire to incorporate the SEPs within existing classroom artifacts, but hinted that they may be lacking a fully developed understanding of how to do so.

When asked what modifications could be made so that typical laboratory exercises could incorporate SEPs, one PSSST was skeptical that students would be able to *plan and carry out investigations* (SEP 3) on their own. She continued that maybe her honors or advanced placement students might be able to, but that would be a stretch. She then stated that she had never experienced anything like the SEPs in her own high school experience.

Other PSSSTs did not express this skepticism concerning ability, but felt incorporation of SEPs would require more time because a different approach would be needed to enact these practices, including scaffolding students though open-ended questioning, playing the devil’s advocate, and allowing, “something to go wrong” with the lab. In general, the statements seem to imply making the laboratory exercises more open-ended and less “cookbook,” thereby allowing students to have agency in the lab. For example, deciding how to collect or analyze the data, being able to start or stop teaching when problems arose, or asking about the application of what was learned.

It should also be noted that none of the PSSSTs ever naively mentioned discovery learning or that students should simply be allowed to attempt to engage in science practices without some type of structure. This again, reveals that the PSSSTs avoided the pitfalls of naively thinking that students can learn science practices on their own.

In response to the question if there was anything that the PSSSTs found helpful for modifying laboratory exercises to incorporate SEPs, the PSSSTs delivered a range of responses, stating that it was important not to introduce too much content before the lab, "so they can see something obvious", not talking above the students' ability, developing questions to ask the students during and after the lab, and generally making the lab more interesting.

PSSST Lisa offered her thinking as she described how to allow students to have greater agency in planning and analyzing data:

> Lisa: I would say more trying to have them…like a lot of times we're always not sure if giving them like a way to set up like a data table. Or maybe, just like the higher level classes, make them…have to come up with a way for how they are going to analyze, be able to analyze their data, so how are they going to write/record their data, how are they going to analyze it by, how are they going to graph it, how are they then going to interpret that. So I guess, just more or less, just having a set of open-ended suggestions questions for them to answer.
>
> Lisa interview, 9:14 - 9:49

Lisa's statements and those from the PSSSTs all seem to be appropriate steps towards planning for incorporating SEPs into their lesson planning, however, other statements suggested these were difficult to enact. Several of the PSSSTs stated that they simply use their mentors' laboratory exercises and try to modify these documents. Of the six PSSSTs, only one related a concrete example of a modification to an existing lesson and another simply stated that he had modified labs. The other four stated that they have not modified labs or tried to create a lab from scratch.

Four of the six PSSSTs interviewed cited the need to follow the curriculum as an impediment to working towards incorporation of the SEPs. Additionally, five of the six PSSSTs also stated that time was a major factor for not incorporating the SEPs into lessons. Two of the PSSSTs stated that time was not available to plan for incorporation of SEPs, two PSSSTs stated that there was not time for enactment of the SEPs, and four of the PSSSTs stated that there was not enough time for them to learn about the SEPs. Again, the one PSSST stated that her school does not allow for laboratory work, thereby negating her ability to incorporate the SEPs.

All of the PSSSTs spoke in *theoretical* terms about modifications that they could or would make to existing classroom work. Five of the six PSSSTs also stated that the students were a major factor for not incorporating the SEPs into lessons, with reasoning ranging from students' ability to engage with SEPs, to not wanting to participate specifically in SEPs, as well as students' general lack of motivation in school. The one dissenting voice stated that incorporation of SEPs would increase students' interest level. Here, Alexis explains a water displacement laboratory exercise where her class is calculating density and deciding the order to stack the liquids in a column:

Alexis:	Um, yes so like I did a lab, um, it was on density and you know there was this standard, ok if you drop something in the liquid and then you, calculate, you calculate the density for it…
Interviewer:	Water displacement or something…
Alexis:	Yah, yah. Um, but what I did was I, um, set up a ton, like eight different unknowns, and each group got four of the unknowns, and they had to calculate the density and then be able to stack them, like in a column.
Interviewer:	Yah.
Alexis:	Um, so, you know they had to work through, ok, well if this one has a larger density, and this one is less dense, which one would we have to put up top…
Interviewer:	Right...
Alexis:	To make it work…
Interviewer:	Right.
Alexis:	Yah, and if we did that, did we calculate it right?
Interviewer:	Yes.

Alexis:	Um, so I think I have taken the concepts, and some of the aspects of what has been given to me…
Interviewer:	Yes…
Alexis:	And definitely tried to adapt it, and that's and that was to try to get them more interested and get more of these practices
Interviewer:	So, so, does that go hand in hand, them [students] being interested in these practices.
Alexis:	Oh, yah, absolutely. For that one I would make the argument that almost all of these…
Interviewer:	So, their interest level would go up if we incorporated these more often?
Alexis:	Yes!
Interviewer:	Well, that's interesting in itself.

Alexis interview, 10:22 - 11:47

This particular example is one that Alexis enacted. It is not exactly clear which SEP she was attempting to illustrate, but it seems clear that she was able to make calculations of density more exciting for the students, who could see from the mixing or non-mixing of the liquids, if the calculations were correct. This was after Alexis stated that she had *considered* allowing something to, "go wrong" in the lab so that the students could attempt to figure out the confounding variable. Again, she spoke in theoretical terms, of letting something authentic happen, not in experience.

The above example of mixing the different density liquids after making calculations may be more of conflation of being "hands-on" than actually incorporating the SEPs. Several of the PSSSTs spoke directly of being "hands-on" and implied at other times as if physical engagement was synonymous with the SEPs.

From the above statements, it appears that using the SEPs is desirable but not really applicable for these PSSSTs, who mainly rely on their mentor's exercises or the school's curriculum. This may indicate that the enactment of SEPs will require a more solid foundation of the enactment of the SEPs as compared to just planning lessons.

In the next section, the PSSSTs' views of the efficacy of the intervention will be explored.

4.2.5 Intervention's efficacy for incorporating SEPs into lesson plans

When PSSSTs were asked if there was anything from the interventions that made incorporation of SEPs into the classroom easier, most PSSSTs responded positively, stating that most of the activities were useful in developing ideas of scientific practices. Comments ranged from the usefulness of the fast plants and the moon phases activities for making the SEPs visible, to the discussions that made visible what good scientific practice looks like, to using the tools, such as the lesson planning rubric for writing lesson plans.

When pushed for an explanation of how or why this was helpful, five of the six PSSSTs felt that knowledge gained translated to their classrooms, their lesson planning, and their development of understanding scientific practices. The remaining PSSST simply felt that the intervention's duration was too brief to be of significance. Here, PSSST Jennifer explains:

Jennifer:	I mean. It gave us like the foundation, I would suppose, like the scaffolding of the foundation, but I didn't find the detail overall to be very useful because it was just a onetime shot…
Interviewer:	I see.
Jennifer:	Here's the information, go forth and use it.
Interviewer:	Uh-hum.
Jennifer:	With not much of how to do it.
Interviewer:	You need more time with that instruction.
Jennifer:	Yah-Yes.
Interviewer:	Ok.
Jennifer:	More time, more examples, more practical, like um, input. Cause I know I, I struggled with making lesson plans, and I think part of it was no one actually ever gave me, like, more concrete how to do it. We had that one workshop and that was, we were kind of set free.

Jennifer interview, 12:10 – 12:55

Here, Jennifer expresses the stress that the PSSSTs encounter in the MAT program. Jennifer stated earlier that her placement was at a new urban school that consisted of students who came from failing schools and is a difficult placement. Jennifer described her school as having students that have significant behavioral problems, some that require involvement from law enforcement.

Jennifer also stated that the entire curriculum was geared towards the end of the year tests and that she felt constrained by the pressure to cover content. Later in the interview, Jennifer reflected that she needed more practical examples on how to engage students in conversation, because she was ill equipped to do so. Here the interviewer is attempting to summarize her previous statements:

Interviewer:	Ideal [situations], great, but when you're dealing with some students that are, uh, challenging, you could use some really concrete examples.
Jennifer:	Especially for someone who has no idea what they are doing, kind of like me. (Laughs) Like I, I was thrown in there and wasn't sure how to make students, do conversation…

Jennifer interview, 16:37 - 16:53

Here Jennifer is making light of how difficult her adjustment to student teaching was and how much support she required. In her case, the SEPs may not have been her first priority. Although, Jennifer's case may be extreme, the other PSSSTs were also placed into difficult settings and encountered many of the same stress related issues that Jennifer encountered. Their responses gave the impression that they were able to use many aspects of the intervention, their placements, and the program in general.

A few of the PSSSTs made comments throughout the interview that implied that they were forced to reexamine their own views of the nature of science, thereby moving to hold more sophisticated views. Here is one example that illustrates this development. PSSST Kurt is reviewing the artifacts during the interview when he sees the interviewer's field notes about the fast plants activity, he then begins:

Kurt:	Ok, that made me realize, which I hadn't thought of before, even during the…that day, I used math to figure out what was typical.
Interviewer:	Yes.
Kurt:	I specifically said actually, yah, you can't, um I am not exactly sure what I said, but along the lines of, with math it was either right, or it's wrong.
Interviewer:	I see.
Kurt:	But, I realized that is not necessarily true, because I am measuring something that doesn't have a right or a wrong.

Interviewer:	Right. Its kinda is about how you measure it and thinking about and how you express…and go from there.
Kurt:	Right.
Interviewer:	I see.
Kurt:	So we use a lot of math and statistics and such, to figure out what might be typical across these plants…
Interviewer:	Right…
Kurt:	But again, like…what, what defines a typical plant?
Interview:	So, so you're saying it was eye opening that it was not just a straight…straight-up answer.
Kurt:	Yah, it wasn't just black and white, it was grey in there. So, I've used that in turn to write my lessons in such, to realize my lessons, to realize not everything is black and white.

Kurt interview, 22:10 - 23:07

This comment seems to demonstrate movement from a naïve realism stance to a more authentically scientific view of how scientific knowledge is generated through scientific practice. Here, Kurt benefits from decomposition of the practice of determining what is meant by typical stem length. By forcing the PSSSTs to examine how they operationalize stem length as they plan an investigation, they are confronted with the realization that practicing science is not as straight forward as normally portrayed in typical laboratory exercises.

Another example is expressed by PSSST Alexis, who shared her initial bewilderment of why she and the rest of the PSSSTs were measuring Fast Plants during the intervention. She states:

Alexis:	Um, when I first did my first lesson plan, um, I didn't emphasis as much on showing the task…
Interviewer:	Yes.
Alexis:	And I think that through all of this [intervention], why am I making them [students] do this anyway.
Interviewer:	Right.
Alexis:	Um, so I think that before I would just brush it off, but seeing all of these things, whether it was thinking how silly is this that I am measuring this fast plant…
Interviewer:	Right, right, right…
Alexis:	And I've done things like this before, like, I am twenty-some years old, why do I have to do this…
Interviewer:	(Laughing)
Alexis:	Um, ok, that task, was making me realize that you know, there was science practice in there. And obviously that is what she [instructor] was trying to get across, and it's like ok, so when I came across my lessons, I need to think, yah, like, this might be a good idea, but why?
Interviewer:	Right.

Alexis:	Um, so I think definitely concentrating on the task more, is something that I got out of those a lot…

Alexis interview, 13:08 – 14:00

Alexis seems to have experienced some cognitive dissonance with the thought of using scientific practices in a classroom setting. The thought of going through the nitty-gritty details of scientific work, in this case the task of developing a protocol for measuring fast plants, seemed out of place when thinking about enacting classroom lessons. Her comment appears to place these scientific practices as a hierarchical stepping stone, where once they are experienced, they are accomplished, and not to be used again. This Fast Plant intervention activity may have forced her to reevaluate her views of the purpose of classroom science, which includes using scientific practices to accrue data, evaluate its legitimacy, and develop models.

Both of the PSSSTs quoted above seem to have recognized the scientific practices in the tasks completed during the intervention. These exercises represented the practice of incorporating the SEPs as potentially being utilized with any secondary class, not just an exercise to be completed for a course. The lesson was then decomposed to make obvious those aspects of the scientific practices that were being utilized during the lesson. The PSSSTs were then able to approximate this practice by writing lesson plans that could potentially be used for their own classroom activities.

When followed up with the question of if there was something else that could be done during the intervention that would help PSSSTs incorporate SEPs into classroom practice, two of the PSSSTs were adamant in wanting simple, easily referenced versions of the SEPs. Here is Robert’s comment:

Robert:	Ya know, this actually sounds probably pretty silly, um, and is probably not at all what you are looking for, but, um, I think if, if we could get some kind of document that would make it easy to reference this when we are working through, like, planning our own lessons and stuff…
Interviewer:	Like this? (Interviewer points to the eight SEPs on a single page.)
Robert:	Yes! Something like this. I think that …

Interviewer:	This is the eight practices.
Robert:	Right. Yah. Cause I, I guess, like, I could always just type, make my own documents…
Interviewer:	Yah, yah, yah…
Robert:	But, like, whenever I went to look for it, I would always have to search, oh, there's the list. It would always take me a couple of minutes to find it.
Interviewer:	So if we gave something that had very explicitly the eight practices, SEPs, and made that a focal point or something like that.
Robert:	I think yah, I mean, cause I, it is just something that I could just easily just, ya know pull up, this is it, or here is my file, here it is. And I can go right to it and think about how to incorporate that into my lessons.

Robert interview, 17:44 - 18:34

Kristine echoed Robert, stating that if the eight SEPs were placed on a single sheet at the beginning of the intervention, she would have used the tool continuously and become more familiar with it. This theme of creating simplistic tools that display the fundamental aspects of the practices became a reoccurring theme. Here Lisa, another PSSST, was describing the value of the learning cycle in her development of thinking in terms of the SEPs. She refers to the moon cycle activity, stating:

Lisa:	I keep, like, going back to the learning cycle.
Interviewer:	Ok.
Lisa:	I would say, like, if it was…I guess…the way she set this up though…with the moon phases…
Interviewer:	Yes…
Lisa:	Was kinda like…this (pointing to a copy of the SEPs that were with the interviewer's notes).
Interviewer:	Yes.
Lisa:	I, I can understand it now, but maybe at the time it was a little bit hard for me to see, but I think that was the point of it.
Interviewer:	Yes.
Lisa:	So, like…I think that actually… in terms of the learning cycle that was the way this was set up was good for seeing those.
Interviewer:	Ok.

Lisa interview, 15:10 - 15:43

As will be seen in the next section, the connection between the learning cycle and the SEPs is an important one for the PSSSTs, who cite it as a primary link to developing authentic views of scientific practice. For both the learning cycle and the SEPs, the key aspect for helping the PSSSTs seems to be about simplicity and utility. Here, the PSSSTs seem to embrace the representations of practice that help to simplify the almost chaotic world of student teaching.

This is reasonable since the PSSSTs are attempting to teach classes as they are taking classes, which require a significant commitment in terms of time, energy, and cognitive work.

In addition to the above requests, others surfaced as well. One PSSST requested explicit training on questioning strategies, including how to prompt students in a manner that would support the SEPs. Yet, another PSSST requested instruction on how to, “wrap-up” lessons so as to avoid leaving students potentially confused when answers are not discrete. Another PSSST asked for concrete examples for non-idealized classrooms. This was echoed by another PSSST, who asked for greater customization for each PSSST’s classroom situation. These requests were in addition to reoccurring requests for more time with the interventions and more time working with other PSSSTs on incorporating the SEPs for their particular classrooms. This exposed the problem of “travel” or generalizeability of the intervention. That is, could these lessons be directly used in working secondary science classrooms? This study only addresses the planning of lessons that can potentially be enacted, and therefore, the enactment of the SEPs may need to be studied elsewhere.

The above comments and those not listed here, indicate that the PSSSTs found the intervention not only helpful, but a necessary first step to developing the skills, techniques, and the craft of teaching the SEPs. The comments also seem to reveal the difficultly in learning and understanding the SEPs as well as their application in the classroom. This is an important note for teacher educators, who may assume that the PSSSTs possess an intrinsic knowledge of SEPs. It is clear in interviewing the PSSSTs that they are not intuitively familiar with the SEPs, have not engaged in SEPs in their own school experiences, and will require significant time to develop the views, abilities, and habits necessary to incorporate SEPs into their lesson planning. In the next section, PSSSTs respond to the question of which, if any, educative supports were helpful in incorporating SEPs.

4.2.6 Educative supports for SEPs

The last interview question inquired about what educative supports (handouts, tables, tools, etc.) helped the PSSSTs incorporate SEPs into the planning process. Five of the six PSSSTs responded favorably overall to the artifacts that were used during the intervention, with Jennifer again providing the dissenting view. Two artifacts that garnered the most positive comments were the learning cycle tool and the lesson plan rubric.

Three of the six PSSSTs expressed excitement about the learning cycle tool, either invoking it by name or by its components (explore, explain, and extend). Another PSSST, Kurt, earlier in the interview also expressed the centrality of the learning cycle to the incorporation of SEPs. Here he enthusiastically stated that:

Kurt:	I don't know, man, I tell you, that this is the gold standard right there.
Interviewer:	Ok. The learning cycle.
Kurt:	Um-hmm.
Interviewer:	Ok.
Kurt:	Um, I mean, based on, I can't think of anything else I would need. If I didn't have this and didn't know what it was, I am not sure what I would say but…
Interviewer:	It would be tough.
Kurt:	Since I have this, I can't think of anything, I could, I could, if I had this and nothing else, if I knew exactly what this meant…
Interviewer:	Yes.
Kurt:	And spent an entire lesson talking about this, a couple of lessons, I think I'd be set.
Interviewer:	Ok.

Kurt interview, 30:36 – 31:05

Kurt then qualified his statement stating that spending more time on the learning cycle, because of its central importance, would be the most beneficial educative support for the

PSSSTs. He further stated that explaining its importance, how it matters and why it matters, and what to do with it, would be the most helpful educative support.

Robert was equally enthusiastic in invoked the learning cycle, and without hesitation he explained:

Robert:	I think in terms of a reference value, I think that one has a high reference value. Something that I can go back to time and time again. Um, a lot, a lot of these others documents, um, like using science to solve the mystery of the frogs, again I think they taught good lessons, uh, in the context of the course, and I think that holds true for the, um, for some of the other documents too, like the intro to the learning cycle, map document. I think they provide good lessons in terms of learning about a topic…
Interviewer:	For your learning about it?
Robert:	Yah. For my learning about it.
Interviewer:	But in terms of the planning?
Robert:	But in terms of the planning, I, um, not, yah, I can't say that I've referenced, um, many of the other documents.
Interviewer:	So the simple learning cycle in science document seems to be the most useful.
Robert:	I think that was the most useful and I would love to have (grabbing the interviewer's SEPs sheet)…
Interviewer:	And if we made a SEPs one that was similar to that?
Robert:	I think that would be very helpful.

Robert interview, 22:19 – 23:20

This sentiment was echoed by a two other PSSSTs who asked for a simple list of the SEPs. The idea of simplistic versions of the SEPs for incorporation of the SEPs is understandable because PSSSTs need this type of scaffolding to compensate for their lack of experience and expertise. Again, the PSSSTs seemed to enjoy the simplicity of the learning cycle because it was of the appropriate complexity for the PSSSTs' ability and experience. Even the more detailed versions of the learning cycle was passed over by the PSSSTs because it was not seen as efficient for writing lesson plans and creating lessons within the time constraints that the PSSSTs must conform. This may also be the reason that the lesson plan rubric was also cited as being a helpful educative support. Here, Kristine expresses her excitement about the lesson plan tool, exclaiming:

Kristine:	This to me was the most useful thing (points to the lesson plan rubric).
Interviewer:	Ok.

Kristine: Uh. And when we got this, it was the best day ever, because I need, I need this sort of…
Interviewer: That structure…
Kristine: Yah. I need a lot of structure. And now I can just do it off the top of my head with structure like this. Yah, I've been doing that in my lesson plans ever since.

Kristine interview, 19:12 – 19:31

This sentiment of longing for structure was expressed by other PSSSTs during the interview. Kristine states that by having a clearly structured tool, she is able to quickly and efficiently produce a lesson plan that she feels will pass muster when evaluated.

When the PSSSTs were followed-up with a question about what other educative supports would help in the incorporation of SEPs into classroom lessons, again, the themes of simplicity and utility emerged. Many of the PSSSTs stated that a simple form of the SEPs that could easily be placed into the lesson planning template would be helpful. Here, PSSST Lisa, speaks about the possibility of incorporating the SEPs into her lesson planning:

Lisa: Yah! Cause I actually know these ones. Because the ones that I am trying to find, like they don't really say what they are, like I have to keep on clicking, on every single one of them.
Interviewer: Um-hmm.
Lisa: So like it does say things about explaining, like, models and stuff like that, analyzing some kind of data, but I just feel like they were more, kind of, down to just these little phrases, it would be a lot easier.
Interviewer: Ok.

Lisa interview, 17:13 - 17:40

Here Lisa is simultaneously excited about using the SEPs for her lesson planning and expressing her dissatisfaction with the current state standards that she is forced to use in her lesson plans. This was not an isolated complaint. Most of the PSSSTs complained about the complexity of the current standards and the effort needed to search out the meaning and make connections to their current lessons using the standards. Here is Kurt's expression of his displeasure with the current state standards:

Kurt: The standards, I think, are useless. That's harsh, but it's true.
Interviewer: What is it about them that make them useless?
Kurt: Because they are not coherent.
Interviewer: I see. The way they are written?

Kurt:	The way they are written is not coherent. They are not structured in a way that a classroom could use them effectively.

Kurt, second interview, 0:45 - 1:04

Kurt and the other PSSSTs seem to be attracted to the eight SEPs because of their simplicity and functionality. Structuring the SEPs as a simplistic tool for the PSSSTs, such as making them as part of the lesson plan template would seem to be an apt addition to the standard lesson plan template, however, this structure may also add to the stress of the lesson planning process. Here, Kristine is expressing her opinion that the SEPs should not be incorporate into the lesson planning rubric:

Kristine:	I would keep them separate.
Interviewer:	Keep them separate.
Kristine:	Yah. I think, that if they are anything like me, and they just want to know, like, I don't know, again I look at this as this is how I am getting graded, this is how to do a correct lesson plan, um, so that, I don't know, is just a point of caution. I looked at this as I'm being graded on my lesson plans.
Interviewer:	You're, as a student…
Kristine:	Here I am a student…
Interviewer:	Here you're a student…using this, and you're like…
Kristine:	Yah. Here I am a student. Here I am a teacher.
Interviewer:	Ok, ok. So if you were a teacher, what would be useful for you to, uh, like, is there anything that you could think that would help to get these incorporated (SEPs) into what you are actually doing in lesson planning?
Kristine:	This sheet (pointing to the SEPs on a single sheet).
Interviewer:	That sheet, right there.
Kristine:	(Speaking softly and suddenly relaxed) Yah…That sheet…You give me that, and I am actually going to ask your for maybe a copy of this (beginning to laugh).
Interviewer:	Ok.
Kristine:	Yah, if this was given to me…
Interviewer:	So this is what you need?
Kristine:	This is what I need. Yah!
Kristine:	Um, If there was a rubric, if there was a rubric set up around this…
Interviewer:	Yes…
Kristine:	That would be very stressful cause that indicates that there is a right or a wrong way to teach the practices, like these practices (pointing to the SEPs).
Interviewer:	So if there was a rubric for this, you would follow it and make sure you hit it?
Kristine:	I would hate it. I don't know. I would, no, no, no. It would be stressful and I might not hit everything and then if your grading me on how closely I hit those markers you've set, I might not agree with, then you know…its
Interviewer:	So grading has something to do with it?
Kristine:	Yah, [absolutely]…for me!
Interviewer:	Can you say more about that, cause this is great stuff.
Kristine:	Um…I can't teach unless I get good grades in this program and pass every class, so even though, ya know, there is a constant pull between my place at (School name) and my place at (University's name), because (University's name) people, you know, have told us, you need to tell your mentor every now and

	again that you have to go off and do (University's name) work. And our mentors are like…
Interviewer:	You're ours!
Kristine:	You're, you're responsibility is your student. And I've just stopped listening to everybody and (laughing)…
Interviewer:	You're pulled …
Kristine:	Yah!

Kristine interview, 20:21 - 22:21

This lengthy segment occurs toward the end of the interview and Kristine, who is visibly tired and a little bit anxious (she was being interviewed after completing her teaching duties and before her evening class at the university) begins speaking more freely. The interviewer detects the change in tone and encourages her to continue speaking.

Kristine's concern with incorporating the SEPs stems from her longing for structure and receiving a good grade. Her perception is that if the SEPs are place onto the lesson plan rubric and she either does not use a SEP or engages in practices not explicitly listed within the eight SEPs, she will become stressed that she is doing something wrong (or at least will be docked in grading). This may indicate that Kristine would feel obligated to use the SEPs when writing lesson plans but understands that typical classroom work rarely actually enacts the SEPs. It may also indicate that Kristine is not confident about her ability to incorporate the SEPs into her lessons.

Kristine also offers insight into the influence grading plays in writing lesson plans. She stated that the grade she received for her lesson plans influences how she writes them, explaining that she writes lesson plans, so she can pass the course, so that she could teach (by achieving a teaching license). This and similar statements made by the PSSSTs seems to allude to the fact that what is written as a lesson plan may not correspond exactly to what is enacted in the classroom; The planning process may have two dimensions: one set of written plans that are written for a formal grade and another set of plans (written or not written) that serves as a guide for what the teacher actually plans to do in the classroom. Inquiring about the alignment of the planned and enacted lessons is beyond the scope of this study, but may be important for teacher educators to be mindful of.

Kristine was interested in a simple tool that could be used for incorporation of the SEPs. She was adamant that this tool should be insulated from any type of assessment, only being used for her planning. This distinction in planning lessons and enacting those lesson plans was further expanded when she expressed the stress she felt as a PSSST (the student) and the PSSST (the teacher). She felt allegiances to both her professors, cooperating teacher, and to her students, which were all in different camps. That is, working as a graduate student in service to becoming a practicing secondary science teacher required her to play several different roles, which were clearly in tension. She needed to write lesson for her course work, enact lessons for her students, and keep her cooperating teacher pleased with what she was doing with his or her classroom. This may help to explain why Kristine feels so uneasy in formally listing the SEPs; because it exposes those tensions that she feels externally (pleasing students, cooperating teachers, and professors) and the internal tension she feels in getting a “right” answer (using the “right” number of SEPs in the “right” manner at the “right” time).

Immediately after this segment of the interview, Kristine spots the template that the researcher used to evaluate lesson plans, which lists the SEPs and the sub-SEPs detailed by the NRC (2012) as shown in Figures 3.4, 3.5, and 3.6. Kristine immediately stated that adding the sub-practices with the SEPs, “has too many words on it.” This idea was echoed several times throughout the interviewing, which suggests that PSSSTs have fragile and underdeveloped views of science that can easily be overwhelmed. This may also help to explain Kristine’s anxiousness in incorporating the SEPs in the lesson planning template. Kristine's unfiltered segment of the interview provided an informative glimpse into the thinking of a PSSST.

A summary of the affordances and constraints PSSSTs feel when attempting to incorporate SEPs into their classroom lessons will be recapitulated in the next section.

4.2.7 Summary of affordances or constraints PSSST feel with incorporation of SEPs

The analysis of the interviews of the PSSSTs revealed the affordances and the constraints the PSSSTs feel when attempting to incorporate SEPs into their lesson planning. The affordances and constraints emerge from both internal and external sources. Within this internal and external dimension, three basic categories of issues emerged. The first was curricular, the next logistical, and the third epistemological. All three of these aspects play a fundamental role in the planning practices of the PSSST, as shown in Figure 4.12.

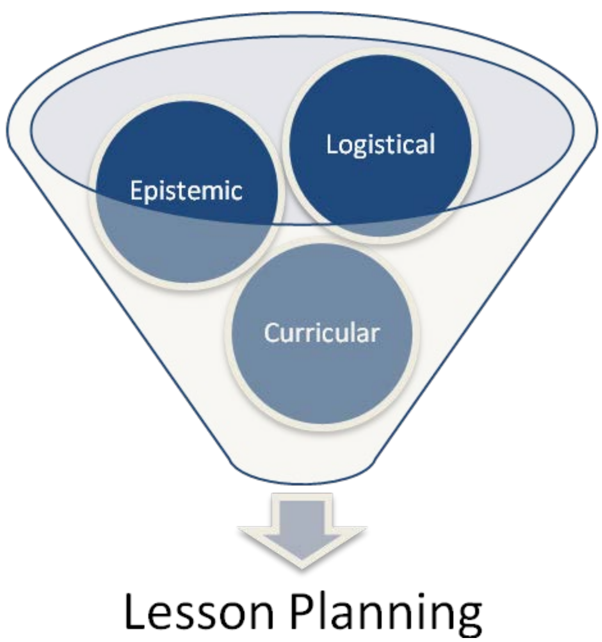

Figure 4.12. The basic categories of issues that emerged from PSSSTs when planning lessons.

The curricular, epistemic, and logistical aspects of lesson planning are not mutually exclusive, but instead, blend into one another and ultimately must work towards the same common goal of helping PSSSTs plan lessons that incorporate SEPs that are palatable for their students and effective for meeting desired outcomes. Issues with each of the three aspects (curricular, epistemic, and logistical) encountered by the PSSSTs is displayed in Figure 4.13 and will discussed in the next section.

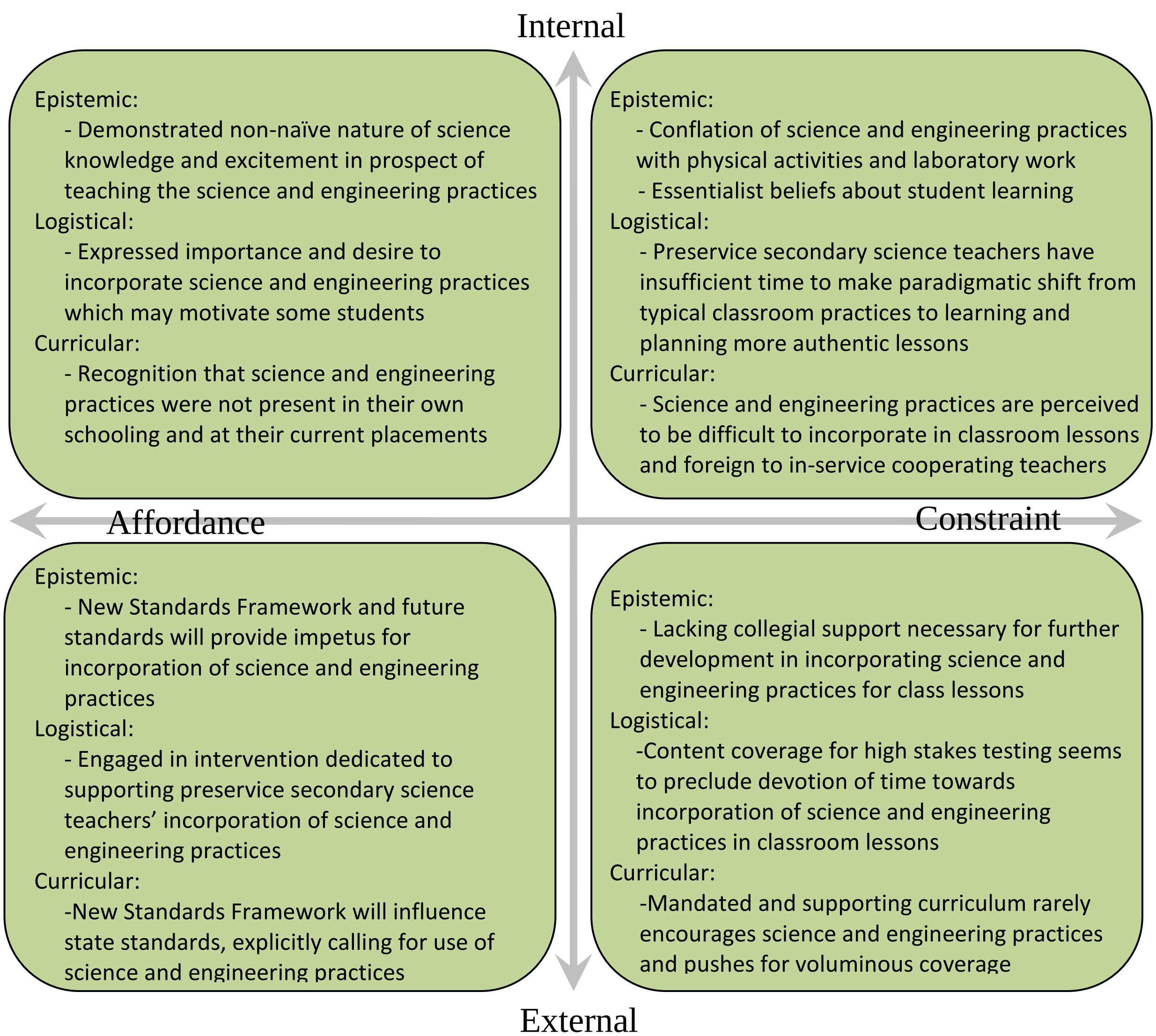

Figure 4.13. The two dimensions of issues PSSSTs encounter when attempting to incorporate SEPs into lesson planning.

4.2.7.1 The affordances and constraints of the curriculum

Throughout the interviewing process, the PSSSTs spoke of the constraints of the curriculum at their placements. Curricular issues are those issues that center on the content that needs to be delivered within each discipline and often the scheduling of that delivery. The curriculum is often set by the school district and the PSSSTs are mandated to follow this curriculum. In addition, the state standards are to be met by the lessons enacted by the PSSSTs.

The PSSST complained about the curriculums' sparse use of SEPs. The complaints most likely resulted from the PSSSTs being asked to incorporate SEPs into lessons and not having a supportive curriculum to scaffold their work. Therefore, the PSSSTs were forced to develop lessons instead of using those provided by the curriculum or their cooperating teacher. The practice of PSSSTs developing new lessons or modifying existing lessons is not unusual. What is unusual is that the PSSSTs are being asked to develop lesson that are different than the experiences that they had as students.

As mentioned in previous sections, many of the PSSSTs had clearly gone throughout their own science education experiences without engaging in activities similar to the SEPs. This may be one of the reasons that some expressed a longing for the structure that had been part of their own experiences, which were most likely non-inquiry type laboratory exercises that rely on set procedural schemes to complete. While only one PSSST directly stated that she had never completed work similar to the SEPs during her experiences as a science student, many of the other PSSSTs seemed to indirectly express a sentiment of newness or foreignness of the SEPs in the classroom.

The intervention allowed the PSSSTs to experience the SEP firsthand, which was counter to their own experiences as students. These intervention experiences were engaged from both a student perspective and from a PSSSTs perspective. This important aspect afforded the PSSSTs targeted instruction on how to develop new lessons, modify existing lessons, and identify aspects of SEPs for their own classroom lessons. These lessons were not anathematic, where these esoteric practices would be deemed useless in the real-world of working classrooms. The lessons presented during the intervention focused on the SEPs and were not domain specific. The lessons also stressed the SEPs as given in the New Standards Framework, which will most likely influence the future state standards (previously released national standards heavily influenced state standards in a trickle-down like dissemination). Therefore the intervention affords the PSSSTs an advantage of having explicit instruction about the intent and goals of the new framework.

In summary, curricular constraints the PSSSTs experience when incorporating the SEPs include internal constraints of lacking authentic experiences in their own student careers and externally as PSSSTs that are restricted to non-SEPs curriculum that are supported by their colleagues, the schools, and administration. In addition, the PSSSTs are constantly reminded of the high stakes testing that does not incorporate SEPs in its assessment.

Conversely, the PSSSTs are afforded the experiences of the intervention, which introduces the PSSSTs to the New Standards Framework, which explicitly calls for inclusion of the SEPs. An additional affordance is that the PSSSTs seem acutely aware that that the SEPs are not present in their current placements, nor was it present in their curriculum when they were students. This recognition is a valuable step towards making systemic change in their planning practices. In the next section, the epistemological issues the PSSSTs grappled with in incorporating the SEPs into their lessons will be described.

4.2.7.2 The affordances and constraints of the PSSSTs epistemological issues

During the interviewing of the PSSSTs, several issues arose dealing with epistemological issues, ranging from the conflation of hands-on activities and the SEPs as well as their views about which students and how students learn. These issues are important for understanding how to best support the PSSSTs as they are asked to incorporate SEPs into their planning of daily lessons.

In the literature review section of this document, it was shown that science teachers (pre-service and in-service) often hold inaccurate views of science and the practices scientists engage. The PSSSTs interviewed for this study did not express naïve views of the nature of science, the scientific method, or misrepresent the SEPs. This would indicate that the PSSSTs have an understanding of authentic scientific practice, despite their lack of classroom experiences engaging with the SEPs as secondary students. This internal affordance is coupled with the external affordance of the current push for incorporation of SEPs by university programs, teacher training workshops, and resource documents like the New Standards Framework (NRC, 2012). All of these offer the PSSSTs hope for future support in incorporating SEPs long after the intervention experience.

While the above items are positive, there are several epistemological constraints that must be addressed for full incorporation of the SEPs. Internal constraints include delineating between activities that support SEPs and those that might not. Several instances during the interviewing seemed to suggest that PSSSTs felt that students must be using their hands or engaging in physical laboratory work to engage in the SEPs. There were also beliefs that the PSSSTs stated about their views of learning that might inhibit the incorporation of SEPs for their students. These included statements that only some students should be exposed to the SEPs because of ability level, age, and or motivation. These views can be problematic because colleagues, in-service teachers, as well as administrators most likely will be unaware of the SEPs and will therefore not be able to engage in conversations that could potentially expose and possibly change these views. In fact, these non-inclusion views may be reinforced by external agents that are not experts in these matters (science education, educational theory, current scholarship, authentic science practice, etc.).

The epistemological views held by the PSSSTs is not isolated to theoretical contemplation about science and science educational theory, but may also manifest in the actions (or inactions) of the PSSSTs. Their epistemological commitments are inextricably linked to how the PSSSTs interact with the curriculum and the logistics of planning for classroom work. This will be explored in the next section.

4.2.7.3 The logistical affordances and constraints of incorporating the SEPs

The theoretical notions of incorporating the SEPs must become practical when writing lesson plans, which are expressly written for how PSSSTs expect their lessons to play out. It is in the lesson plan that the PSSST must contemplate how their skills, beliefs, and knowledge can be coupled with the curriculum to help make meaningful the content that they are required to cover.

During the interview, several of the PSSSTs spoke excitedly about the SEPs. That excitement diminished when asked how they actually enacted these practices in their classrooms. This was because they felt a major time constraint in learning about the SEPs, developing the skills necessary to create and modify existing lesson plans to incorporate SEPs, and the time needed to enact them within the time allotted in the curriculum. This external pressure of high stakes testing was mentioned by name by two of the PSSSTs during the interview and hinted at by the others as a constraint to incorporating the SEPs.

The external pressure was coupled with the internal constraint that the PSSSTs seemed to feel in being required to carry out a paradigmatic shift from typical classroom practices towards those that incorporate SEPs. The intervention attempted to demonstrate how existing lessons could incorporated SEPs, thereby negating the need for complete rewrite of lessons. However, the stress detected during the interview with the PSSSTs indicates that incorporation of SEPs requires a significant shift from current practice.

The PSSSTs were at times seemingly torn by their theoretical convictions for incorporation of the SEPs and the practical and logistical constraints that seem beyond their control. This internal dilemma can be considered an affordance, in that it indicates that the PSSSTs are experiencing cognitive dissonance about how they engaged school science as students and how they promulgate the benefits of engaging in authentic scientific activities with their students. This optimism if further advanced by the external affordances offered by the intervention, which helped to relieve some of the cognitive dissonance by demonstrating practical applications of the SEPs and how to plan for them accordingly.

5.0 DISCUSSION

In this chapter, the entire study will be summarized, describing the results, the implications of these results, and the research questions that will guide further research. Section 5.1 will begin with a brief summary of the impetus of the study. The methods utilized as well as the research questions will also be included. Section 5.2 will discuss the significant and non-significant findings for each of the research questions. The findings will connect to the literature reviewed in chapter 2. Section 5.3 will attempt to glean meaning from these results and will provide perspective for each finding concerning the PSSSTs' ability to plan for lessons that incorporate the SEPs. Section 5.4 will offer practical applications of the results including information that other researchers and teacher educators may use for their planning. Section 5.5 will offer suggestions for future research concerning the planning and implementation of the SEPs for PSSSTs.

5.1 SUMMARY OF THE STUDY

The field of science education has been grappling with how to improving the overall quality of science experiences for students for over a century. After several iterations of major policy decisions, reform movements, and changes in educational theory, the New Standards Framework (NRC, 2013) has been unveiled as the summation of this work. Within this framework, the SEPs represent those practices in which scientist engage that have been identified as important for students to learn. What is known is that science teachers typically do not attend to reform based teaching, such as SEPs (Capps & Crawford, 2013). What is not yet known is how to best accomplish the necessary transformation of teaching practices of teachers, so that SEPs become a regular part of science lessons. PSSSTs are apt agents for this change because they are not yet set in their methodology; however, these PSSSTs have vast experiences with those methods and practices that the New Standards Framework is attempting to alter (Lederman & Latz, 1995; Mellado, 1998). That is, the majority of their experiences as science learners do not reflect the best practices that the NGSS are advocating – including the engagement of students in SEPs as a regular part of their science learning experience.

Past and current research indicates that teacher practices, typical classroom lessons, and the roles and routines that are pervasive in schools, are robust, resistant to change, and are maintained by the curricula, textbooks, and state testing (Abd-El-Khalick, Waters, & Le, 2008; Ford & Wargo, 2006; Joram, 2007, Remillard, 2005). It is, therefore, a significant task to change how PSSSTs think about teaching, learning, and how classroom lessons should be planned. It is within this context that this study is situated.

In this study, an intervention of the PSSSTs was given on a series of all day workshops which were held on several weekends of the fall semester for the MAT PSSSTs seeking teaching certification as they complete their Secondary Science Methods 1 course. The workshops focused exclusively on how to plan lessons, how to incorporate the learning cycle into the planning of lessons, and how the SEPs can be utilized in a working classroom. The PSSSTs were engaged as both students and teachers as they participated in science learning activities and subsequently "unpacked" or decomposed those activities so as to make obvious the planning required to design and facilitate learning in such lessons. The PSSSTs wrote lesson plans before, during, and after the intervention and these lesson plans were analyzed to answer the following research questions:

1) Are SEPs represented in PSSSTs' lesson plans after viewing the SEPs? If so, which SEPs do the PSSSTs incorporate?
2) How successful are the PSSSTs at incorporating SEPs into their lesson planning during the intervention?
3) What is the longevity of the instructional intervention on PSSSTs' lesson planning when instruction is no longer given to incorporate SEPs? Which, if any, SEPs (or sub-SEPs) remain in the PSSSTs' lesson plans after the intervention?
4) What are the affordances or constraints that PSSSTs perceive when planning for SEPs? How do these affordances and constraints influence the incorporation of particular SEPs?

To answer these questions, quantitative and qualitative methods were employed with six randomly selected PSSSTs, from a total of eleven PSSSTs, who were students in a MAT program at the university. All of these PSSSTs were enrolled in Secondary Science Methods 1 and were student teaching in urban schools.

Lesson plans from these six selected PSSSTs were analyzed before, during, and after an intervention to see if SEPs were incorporated into the PSSSTs' lesson plans. The intervention was based on the Grossman et al. (2009) model, which proposes that novices learn to engage in expert practices through experiences with representations of those practices, carefully decomposed into component sub-practices, followed by participation in scaffolded approximations of the expert practices. The interventions provided activities, tools, and experiences for PSSSTs that represented how the SEPs could be incorporated into classroom lessons. The instructor then helped with the decomposition of the practices so that the PSSSTs could examine the important aspects that supported the lesson. Finally the PSSSTs were able to approximate these practices through planning of lessons that incorporated SEPs.

As the lesson plans were analyzed for the use of the SEPs, analysis to discern patterns in this data was completed by breaking the SEPs into sub-practices. The frequency of each SEP and the sub-SEPs for each PSSST was calculated.

The same six PSSSTs were interviewed after the intervention and while they were writing lesson plans primarily as student teachers, to determine what affordances and constraints they felt when attempting to incorporate the SEPs into their lesson planning. In the next section, the findings from the data analysis will be presented and each research question will be answered in order.

5.2 FINDINGS

In this section, each of the research questions will be presented with a summary of the findings detailed in chapter 4. The first research questions asked *whether SEPs were represented in PSSSTs' lesson plans after viewing the SEPs.* The analysis shows that some of the PSSSTs did incorporate SEPs into their pre-intervention lesson plans. Of the six PSSSTs' lesson plans evaluated, three contained at least one SEP.

The second part of research question 1 asked, *if PSSSTs did incorporate SEPs, which SEPs did they incorporate?* The SEPs used in the lesson plans written by the PSSSTs were dominated by SEP 6 (constructing explanations), which accounted for four of the five SEPs used by the PSSSTs. The lone remaining SEP was SEP 3 (planning and carrying out investigations). SEP 4 (analyzing and interpreting data) was not represented in any of the PSSSTs' lesson plans during the pre-intervention phase.

The second research question asked *how successful the PSSSTs were at incorporating SEPs into their lesson planning throughout and after the intervention*. The PSSSTs had much higher rates of SEP incorporation during and after the intervention compared to the pre-intervention levels. All six of the PSSSTs incorporated at least one SEPs into LP2 and four of the six PSSSTs incorporated at least one SEP into their LP3. LP2 had 14 instances of sub-SEPs incorporated into the lessons and LP3 had 12 occurrences of sub-SEPs. This was up from five in LP1. The number of unique sub-SEPs also increased by from four in LP1, to five in LP2, to six in LP3.

In summary, only half of the PSSTs incorporated SEPs prior to intervention and those SEPs were overwhelmingly related to explanation. In contrast, following the intervention, the PSSSTs were all able to incorporate at least one SEP into their lesson plans and most were able to incorporate more, as there was a wider variety of SEPs represented in these later plans. This indicates that the intervention was effective in helping the PSSSTs to develop the skills for planning lessons that incorporated SEPs.

Coding for the SEPs required meeting the sub-SEP as written by the New Standards Framework, each of which included conjunctive statements that would preclude non-rigorous incorporation of the SEPs. Because of the selectivity in this coding process, any lesson plans that were coded for a sub-SEP were necessarily central to the lesson. As mentioned above, the PSSSTs did incorporate the SEPs into their lesson planning during the intervention. Therefore, the PSSSTs' lesson plans evaluated did in fact incorporate SEPs and they played a central role in the lessons.

The third research question asked *what was the longevity of the instructional intervention on PSSSTs' lesson planning when instruction was no longer given to incorporate SEPs*? The PSSSTs continued to include SEPs into their lesson plans at higher than pre-intervention levels after they were no longer required to do so, averaging 83% of PSSSTs incorporating at least one SEP into their lessons for both weekly plan 4 and weekly plan 5. In addition, the pre-intervention rate of PSSSTs' incorporation of sub-SEPs after the invention was 12 for WP4 and 18 for WP5, which was up from five in LP1. These numbers indicate that the intervention has longevity in its effect.

The second part of the third research question asked *which, if any, SEPs (or sub-SEPs) remained in the PSSSTs' lesson plans after the intervention?* Again, the dominant SEP was SEP 6 (constructing explanations) which made up 67% of the occurrences of sub-SEPs during weekly plans 4 and weekly plans 5.

SEP 3 (planning and carrying out investigations) and SEP 4 (analyzing and interpreting data) were present during both weekly plans 4 and weekly plans 5, and is the only period of evaluation in which all three SEPs were represented. Recall that SEP 4 (analyzing and interpreting data) was absent during the pre-intervention lesson plans and SEP 3 (planning and carrying out investigations) was absent during lesson plans 2 and 3. This indicates that the use of SEPs broadened after the intervention and the overall diversity of the sub-SEPs increased from the pre-intervention level of four sub-SEPs, to 5.5 sub-SEPs during the intervention (LP2 had five and LP3 had six sub-SEPs), and finally to eight sub-SEPs in WP4 and eleven sub-SEPs in WP5.

As detailed above, the range of SEPs used broadened not only from the pre-intervention level, but also continued to increase past the level that was attained during the intervention. The last set of weekly plans analyzed had almost three times the number of unique sub-SEPs as that of the pre-intervention plans. This coupled with the fact that all three SEPs were represented in the weekly plans, and that the number of sub-SEPs per plan evaluated increased, demonstrates that the SEP were being more completely used by the PSSSTs than during the pre-intervention phase.

The fourth research question asked was, *what were the affordances or constraints that PSSSTs perceive when planning for SEPs*? *How did these affordances and constraints influence the incorporation of particular SEPs?* The PSSSTs were interviewed and revealed that there were affordances and constraints that were both external and internal. Within this division, three main themes emerged. The first was the curriculum, where the external constraints presented the PSSSTs with the challenge of attempting to incorporate SEPs while completing the mandated curriculum. An affordance of the curriculum was that of an external push from the *New Standards Framework* and similar initiatives that are pushing for reform pedagogy. Internal curricular affordances included an excitement for using the SEPs in lessons, recognizing that they (PSSSTs) had learned differently as students than what they were being asked to teach, and that using these SEPs in classroom lessons can be motivating to some students. These internal affordances are tempered by the perceived difficulty in incorporating SEPs into classroom lessons, the foreignness of the SEPs in the classroom, and their concern with being the change agents within a school district.

The second theme centered on epistemic issues and is related to the curricular and the logistical issues. The internal constraints center on how the PSSSTs understand science and its practices. The PSSSTs seem to conflate hands-on activities with the SEPs. In addition, they seem to emanate essentialist ideas of students needing to be a particular age, have a particular ability, or be the correct type of learner for incorporating the SEPs. An external constraint is the lack of support necessary for further development in the school setting of more sophisticated views of authentic scientific practice and views of student learning, and the connection to incorporation of SEPs. The epistemic affordances include: lacking many of the deleterious views of science that are pervasive in the school science classrooms, such as the scientific method or discovery learning. An external affordance for epistemological matters is the *New Standards Framework* and other programs that are slowly working their way into classrooms. The PSSSTs are already familiar with these initiatives as well as reform pedagogy, thereby giving them an advantage over other educators who are not as well versed.

The curricular and epistemological issues are related to the logistical affordances and constraints of incorporating SEPs. Internal logistical constraints include the lack of "digestion" time needed to shift current practices to reform practices of incorporating SEPs. This is often the result of the external constraint of needing to spend class time preparing for high stakes testing or following the mandated curriculum, which tends not to include the SEPs. The logistical affordances are the experiences that the PSSSTs gained during the intervention which allowed them to experience firsthand what their students will encounter when engaging in the SEPs. These findings will be related to the literature review in the next section.

5.3 CONCLUSIONS

In this section, the findings will be related back to the literature review in an effort to glean meaning from them, including some surprising findings. The first surprise in the findings was that the PSSSTs incorporated some of the SEPs in their initial lesson plans before the intervention. This was refreshing because other studies indicated that it was unlikely that the PSSSTs would incorporate SEPs because of the reported difficultly in enacting inquiry like activities (Davis, Petish, & Smithey, 2006). This study does not measure enactment of inquiry, but increase the chances for successfully enacting inquiry because the PSSSTs have seen representations of practice during the intervention and decomposed the practice when writing lesson plans.

In addition, the act of having the PSSSTs read about the SEPs seemed to be a weak educative tool for incorporating SEPs into a lesson plan. (Recall that the preintervention lesson plan that the PSSSTs wrote had only the reading describing the SEPs as the educative support for writing the lesson plan.) The fact that PSSSTs incorporated SEPs may indicate one of several things which will be described below.

The first is that the educational field is having some effect in a trickledown manner. For the last two decades, research has been pushing for incorporation of nature of science knowledge and inquiry (AAAS, 1993; NRC, 1996, 2000); both are represented in national education documents that are regularly used when making state standards and are therefore becoming slightly more visible in classrooms. This explanation seems unlikely because this vision of reform education remains distant as demonstrated by the *New Standards Framework* and other documents (NRC, 2012, 2005), A second possibility is that the PSSSTs may have had research experiences in the past that would predispose them to using reform techniques (Windschitl, 2003). This is not unreasonable because the university program in which the intervention takes place is a prestigious one that attracts high caliber students from high ranking schools that may have provided the students with internships or other science related experiences. It is therefore a possibility that the PSSSTs may already hold epistemological viewpoints that are rather sophisticated concerning science. This is consistent with the findings in this study that reported earlier that the PSSSTs did not state nor demonstrate naïve epistemological views. This coupled with Tsai's (2006) study that found that a teachers' scientific epistemological viewpoint correlated consistently with their science instruction. This means that if the PSSSTs had more authentic views of science, they may tend to use more constructivists teaching techniques like inquiry, which is closely aligned with the SEPs. Kang and Wallace (2004) concur that teachers' epistemological beliefs are clearly reflected in their teaching practices. However, they also point out sophisticated views of science are necessary but not sufficient for sophisticated teacher practices. Rebutting studies presented later in this section will also cast doubt upon the relationship between beliefs and practice.

Another possibility is that the PSSSTs, who are very good, experienced students, simply took the cue of the intervention instructor passing out information as a directive to use that information for the course work, including the first lesson plan. However, without additional forms of data, such as lesson plans written before the first class meeting of the Secondary Science Methods 1 course, it is not known if the SEPs would be present. All that can be said is that the SEPs were in some of the pre-intervention plans.

It was not surprising that the most utilized SEP was that of SEP 6, constructing explanations. School science is often taught as a series of explanations that the students are to learn, sometimes called, “a rhetoric of conclusions” (Schwab, 1962). However, school explanations have been found wanting. Sandoval (2003, 2005) found that constituent parts of the explanations in student work in science classrooms were often devoid of conceptual and epistemic components. Ruiz-Primo, Li, Tsai, and Schneider (2010) found that while explanations are a staple of classroom work involving inquiry like experiences, most students generate explanations that lack supporting data or reasoning. SEP 3 (*planning and carrying out investigations*), SEP 4 (*analyzing and interpreting data*), and SEP 6 (*constructing explanations and designing solutions*) incorporated together in a lesson provide an opportunity for students to form conceptually and epistemologically based explanations, where claims are made and backed with data and supported with reasoning. Alone, sub-SEP 6A (*construct their own explanations of phenomena using their knowledge of accepted scientific theory and linking it to models and evidence*) and sub-SEP 6C (*offer causal explanations appropriate to their level of scientific knowledge*) are both lacking in claim making and are most closely aligned with typical classroom practice. That is, providing statements as fact without concern of others asking for backing.

It is not surprising that the sub-SEP 6C would be used most often because of its simple one sentence structure that lacks conjunctive statement and is rather vague in its criteria. This provided the coder with significant leeway in what is acceptable as a positive code. Sub-SEP 6A is a little more surprising, because of the need for evidence in the form of theory or a model. This is because models, a staple of authentic scientific practice, offer an alternative to the scientific method for producing epistemic evidence (Windshitl & Braaten, 2008b).

Michael Shermer (2001) credits Darwin as stating the single deepest statement ever made about the nature of science, now known as Darwin's Dictum. The essence of this dictum is that every scientific statement or observation must be for or against a theory, hypothesis, or model. This apt description helps to explain the role of models in scientific work. This added criterion is what often differentiates science *like* tasks from authentic science tasks (Windschitl, 2004). The positive code for sub-SEP 6A demonstrated that the explanation is nested in or towards a theory or model. This is a positive step from simply giving an answer and towards developing authentic scientific practice because science is fundamentally a theory-building endeavor. It may therefore be no small exaggeration to state that the calling for theory or a model indicates high level scientific explanations (especially when coupled with SEP 3 and SEP 4 as mentioned above).

Throughout the analysis of lesson plans of the PSSSTs, models appeared several times, but were not analyzed in this study. The reason that this SEP (SEPs 2 - *developing and using models*) may have arisen so often is that the textbooks regularly cover theories (kinetic molecular theory, Darwinian evolution, field theory, etc.). At first glance, this seems to be the one area in which the textbooks have embraced the SEPs, however, the SEPs call for the construction of, using, and revising models, which is an extraordinary event in typical science classrooms and this use of models is clearly not present in textbooks (see AAAS (2005) for a review of bench-marked textbooks). It should be noted that SEPs 2 (*developing and using models*) was not selected for this study because it did not seem probable they would be present in the PSSSTs lesson plans. Regardless, the use of the modeling SEP is beyond the reach of this study, and therefore models were only counted when they were in support of explanations.

Windschitl (2004) found that PSSSTs found inquiry difficult in designing and carrying out their own projects, especially in developing a question and designing a study. For this reason, I did not expect to find any *planning and carrying out investigations* (SEP 3) in the lesson plans of the PSSSTs. Aside from a single appearance, this SEPs was absent in the preintervention lesson plans and during the interventions phase that included LP 2 and LP 3. It was only after the intervention that this SEPs began making an appearance in the lesson plans of the PSSSTs.

This may seem like an unlikely scenerio, that of PSSSTs using SEP 3 *(planning and carrying out investigations*) only after the intervention was completed. Brown and Melear (2006) may have an answer to this conundrum. Their reseach showed that most first year teachers considered themselves to have student-centered teaching styles, however when actually observed, they were almost exclusively teacher-centered. What the Brown and Melear (2006) found time was that over time, the teacher actions and beliefs became more congruent. That is, the belief became partially realized. It may be that the PSSSTs in this study felt that they were having their students designing and carrying out investigateions, but were not quite capable of such high level tasks until the acrued more experience. If this hypothesis is true, then these same PSSSTs in this study might be expected to continue to increase the use of SEPs each year they gain experience. This is clearly beyond the scope of this study, but a longitudinal study could be used to answer this question.

It was expected that SEP 4 (*analyzing and interpreting data*) would be incorporated at higher rates than SEPs 3 (*planning and carrying out investigations*) because many laboratory assignments include sections of analyzing and interpreting data. However, SEPs 4 (*analyzing and interpreting data*) as written with the sub-SEPs, again, is filled with conjunctive statements and qualifiers that preclude superficial analysis and interpreting data from being counted during coding. As with SEP 6 (*constructing explanations*), SEP 4 (*analyzing and interpreting data*) required connections to initial hypothesis and models in some of the sub-SEPs codes, which resulted in not a single sub-SEPs being present for the pre-intervention lesson plans. The lesson plans produced by the PSSSTs during the intervention jumped precipitately, which indicates that the intervention activities had the intended effect.

The slight drop off of the incorporation of SEPs by the PSSSTs was not surprising when the intervention ended because the lesson plans produced by the PSSSTs during the intervention were being graded for the Secondary Science Methods 1 course. What is interesting though is that the levels of all three SEPs investigated in this study, remained at higher levels than that at preintervention levels. Again, during the weekly plans, the PSSSTs were no longer being graded for their lesson plans and were writing lesson for their placements, not the Secondary Science Methods 1 course. It was therefore expected that the PSSSTs would stop incorporating SEPs when they were no longer mandated. Davis, Petish, & Smithey (2006) reported that both in-service and PSSSTs alike struggle with teaching inquiry, enacting their instructional ideas, and tend to be resistant to innovative practices. For these reasons I did not think that the PSSSTs would continue to incorporate SEPs at pre-intervention level, let alone above the pre-intervention levels. This is because for the pre-intervention lesson plan, the PSSSTs were given text listing and explaining the SEPs, which could serve as a cultural cue to incorporate SEPs. Even without explicit instructions to do so, the PSSSTs may have attempted to incorporate the SEPs because they understand the expectations of their teachers and professors implicitly. An additional reason for not expecting continued incorporation of the SEPs is that typical school science (textbooks, standards, end of the year testing, etc.) does not mandate the SEPs.

The fact that the PSSSTs continued to incorporate the SEPs into lessons is also interesting because Beyer and Davis (2009) point out that while educative supports can help undergraduate pre-service elementary teachers to complete their lesson planning, it is insufficient to change practice. That is, they found that when the educative support is removed, pre-service elementary teachers stop attending to those features. In this current study, SEPs use seemed to broaden with time after the requirement to do so was removed. The differences in the results could be attributed to the differences in the sample used for each study. Beyer and Davis (2009) were testing undergraduate elementary education teachers, while this current study used graduate students.

Unlike elementary teachers, secondary science teachers specialize in science, often majoring in a field of chemistry, biology, or physics. For this reason, graduate science students may have been closer epistemologically and philosophically to authentic science and may be more comfortable with science content than the pre-service elementary teachers, who do not specialize in science. In addition, many of the graduate students may have had numerous science experiences and multiple laboratory courses in their repertoire. These science degreed graduate students may have been freer to concentrate on the pedagogical aspects rather than learning content and thereby allowed them to reduce the cognitive step of incorporating the practices learned during the intervention experiences.

Beyer and Davis (2009) also reported that the elementary teachers were using inquiry because of the motivational aspect it had on their students, not because of the authentic science aspect. This may be the reason for their results; the elementary teachers did not find authenticity in the application. The pre-service elementary teachers were playing with new interesting ideas and techniques, but could not envision real applicability in their classrooms. Therefore when mandate was lifted, they stopped incorporation.

Other researchers have also reported success with intervention style professional development. Lotter, Harwood, & Bonner (2006) showed that a two-week summer institute dedicated to a professional development program for in-service secondary science teachers that centered on inquiry, had a positive effect on teachers perception for using inquiry based techniques in their classrooms. The concern with this study is the idea of perception verses reality. Teachers may percieve that they are changing their practice but may not be. Mellado (1997, 1998) and Mellado, V., Bermejo, M. L., Blanco, L. J., & Ruiz, C. (2007) showed that PSTs' conceptions about teaching and learning did not necessarily correspond with their classroom behavior and may even be in direct opposition. Similarly, Tobin and McRobbie (1997) also showed that the enacted curriculum can be in direct contrast to professed beliefs.

This is a limitation of this study; there is no data to confirm enacted practice, only planned practice. This is problematic because while the enactment of the curriculum is influenced by the teachers beliefs, knowledge, and disposition (Remillard, 2005), beginning teachers rely heavily rely on textbooks for guidance (and possibly to master the content) (Sanchez & Valcarcel, 1999), other teachers (including memories of their cooperating and their favorite teachers) (D. S. Brown, 1993), all of which have been shown to be far from reform pedagogy.

This last point, that of the influence of teachers on the PSSSTs, may also be a positive one in this current study in that the instructor of the intervention modeled authentic, reform, and applicable practices to the PSSSTs and demonstrated how to plan for such activity in their own classrooms. Lederman and Gess-Newson, (1991) showed that PSSSTs normally attempt to learn and apply what they learn from their cooperating teachers. It is not, therefore, difficult to conceive PSSSTs wanting to emulate the instruction of the SEPs after positive experiences in the intervention as demonstrated by the intervention instructor. Also, by learning and then planning for SEPs to be incorporated into lessons, the PSSSTs could legitimate their position as contributing teachers and gain status into the teaching community (see Lave & Wenger, 1991 for a description of legitimate peripheral participation).

Viewed another way, it may not be that surprising that PSSSTs continued with their incorporation of SEPs because they saw the successful enactment during the intervention. Windschitl, Thompson, Braaten, and Stroup (2012) state that once shown the efficacy of new techniques, teachers can and will make the switch to the more productive methodologies. In this study, the majority of the PSSSTs reported a positive experience during the intervention. It seems from the interview data that the PSSSTs' conceptions of what happens or is potentially possible within a classroom may have been changed during the intervention.

Echoing Winschitl et al. (2012) is Martin del Pozo, Porlan, and Rivero, (2011) who state that PSSSTs views, while robust, entrenched in experience and belief, may be altered to more fruitful, authentic views. High quality professional development experiences are capable of such transformations (Jeanpierre, Oberhauser, and Freeman, 2005). This study may have been an example of high quality instruction that convinced PSSSTs to adopt practices early in their development so that they could pull-off high level instruction without necessarily needing to replace engrained, but not yet enacted, teaching practices. This of course was possible because the PSSSTs were at the beginning of their teaching and planning development.

The results, mentioned above, suggest that intensive training that occurs early and during the development of the PSSSTs notions of what science lesson plans should encompass, may have the effect of producing normative practices. Once these normative practices are adopted by the PSSSTs, it may require more work on the part of the PSSSTs to change these practices than to simply continue following their previous practices (if they had any). In this study, that means that getting PSSSTs to write lesson plans that incorporate SEPs initially, sets an internal template in the minds of the PSSSTs so that incorporating SEPs has a “just because” quality, typical of any repetitive scheme. One PSSST had mentioned this in her interview, stating she had become “set in her ways” midway through the Secondary Science Methods 1 course.

5.4 IMPLICATIONS

The results of this study indicate that the PSSSTs that receive an intensive intervention that coincides with methods in teaching course work might yield PSSSTs that are able to incorporate SEPs into their lesson planning. It also appears the Grossman et al. (2009) model of representing the practice, decomposition of the practice, and the approximations of practice is an effective model for helping PSSSTs to incorporate SEPs in to their teaching practices by allowing them to see what the practices looks like, what features are important to concentrate on, and how to begin the process of accommodating these practices into current planning practices.

Hubbard and Abell (2005) found that pre-service elementary teachers who experienced inquiry science were able to recognize and learn from inquiry and better able to apply an inquiry approach to their lesson planning than teachers that had not. This seems obvious. It may also seem understandable that many elementary teachers do not have experiences in inquiry, authentic science, or the SEPs. What might be more surprising is that only about one in five graduate students in science education report having had the opportunity to design and conduct independent investigations during their own precollege and college careers (Windschitl and Thompson, 2006). It is this reason the Grossman et al. (2009) model may be so important. While teacher educators may assume that PSSSTs who have undergraduate science degrees, have had experiences that allow them to make connections to the SEPs, representing the practices during an intervention or course work ensures that they have at least one opportunity to engage authentically in scientific practices. The Grossman et al. (2009) model allows for the PSSSTs to dissect and examine the practices so that they can see the planning required to pull-of these practices during classroom lessons and how to plan accordingly. The PSSSTs eventually will need to be able to approximate these practices, which can be accomplished either through planning lessons or attempting to enact these lessons.

The results also indicate that PSSSTs will incorporate SEPs into their lessons at a much higher rate when they are mandated to do so. However, the rates at which PSSSTs incorporate SEPs into their lesson planning can also have longevity if the PSSSTs see their utility and applicability in the classroom, are given simple educative tools that relate cleanly the learning theory (e.g. the learning cycle) to the typical practices that are inherent in the field (e.g. lesson planning). The gains may require time to sprout as the PSTs grapple with the real pressures to conform to their school environments while simultaneously being the agents of change.

The PSSSTs seem to understand that they are both expected to be members of the teaching community and be change agents. What these PSSSTs need is the appropriate support to help them succeed at both roles. They need learning theory that is not overwhelming, they need teaching tools that are easily accessible, they need templates that are efficient, and most of all, they need time to assimilate their new roles, time to plan high-quality lessons, time to reflect about their performance, and time to make adjustments.

5.5 FUTURE RESEARCH

The significance of this study is that the PSSSTs are capable of planning for engaging students in SEPs when supported appropriately. Of course the primary support remains with the intervention instructor who represents the SEPs through mock lessons, decomposes the lesson to point out where, how, and why the SEPs are being incorporated, and who supplies the teaching tools so that the PSSSTs can attempt to approximate the incorporation of the SEPs into their lesson planning. Other support is needed by the PSSSTs and includes support from other university programs and courses (who can hopefully begin to integrate the SEPs), patience from cooperating teachers (who feel pressure to cover their typical content), and tolerance from the school districts (who burden the results of high stakes test results). All of these agents need to be investigated to determine the current level of support for the SEPs, and more importantly, what is needed to increase that support.

The intervention, as described in this study, had a positive effect on the lesson planning of the PSSSTs as they incorporated the SEPs. However, there is a spirit written into the New Standards Framework that has yet to be reached. When reading the New Standards Framework, it is not clear at what rate the SEPs should be covered and more importantly how to integrate them with current state standards. It is a utopian dream to implement the SEPs starting in the elementary grades as described by the New Standards Framework and working through to the secondary grades. The real world of schooling requires preparing for high stakes testing and hitting the vast number of state mandated standards. Pre-service and new in-serivce teachers feel this stress and grapple to find some semblance of normality in this tension, often by incorporating their personal views, their experiences in science and education, their students needs, and the structure of their school (Bianchini, Johnston, Oram, and Cavazos, 2003).

An example of this tension is in the PSSSTs decisions to include the SEPs in their lessons, knowing that they are not going to be on the end of the year assessment. This is a testament to their commitment to enact practices that are important, but may ultimately hurt their overall test scores. So while most of the sub-SEPs utilized by the PSSSTs in their lesson planning are disparate and often at the lowest level and frequency necessary for achieving a code as described by the New Standards Framework, they are nonetheless incorporating them.

The spirit of the New Standards Framework is one of student inquiring with agency about natural phenomena. That includes students' determining what questions to pursue, students designing the experimental designs and protocols for data collection, and students determining how to best analyze the data. Throughout this process, students' would critique their own work, looking to root out uncertainty by critiquing each other's work. In this theoretical classroom, the SEPs and the sub-SEPs would consistently, coherently, and completely be utilized daily. In reality, what is needed is an example curriculum that is designed for teachers that is realistic in its schedule, realistic in the proposed objectives, and correlates with an assessment scheme that mirrors the work that students are being asked to complete. Ball and Cohen (1996) made similar pleadings almost two decades ago and it also remains a utopian dream, so I will offer some more realistic future research projects.

Limitations of this study provide ripe areas for future investigations. First of which is the lack of data from before the SEPs were given to the PSSSTs. Any similar future study should ask PSSSTs to write a lesson plan before the SEPs are given. When initially proposing this study, it was assumed that no SEPs would be incorporated into the lesson plans of the PSSSTs unless the SEPs were offered. I was surprised by the number of SEPs that were incorporated when the SEPs were given. This new test would determine if the act of giving the PSSSTs the SEPs was the cause for the incorporation or if the PSSSTs would have written their plans to incorporate the SEPs (in this case - explanations) anyhow.

Another potential research project should investigate how the SEPs are enacted by the PSSSTs. It is unlikely that the lesson plans will be followed exactly, but determining the level of correspondence between the planned and the enacted lesson may further expose difficulties that the PSSSTs have using the SEPs. This would require either observations of the PSSSTs (in person or with video) or self-reporting. Both have drawbacks, but may be managed by appropriately selecting the sample.

Future research should also look at the remaining SEPs. This study targeted three of the eight SEPs. It may be determined that some of the SEPs are more difficult to incorporate than others. If certain SEPs are more applicable to a particular subject, this could help to trim the standards for each discipline, thereby making more realistic domain specific standards that target particular SEPs.

Finally, the PSSSTs in this study demonstrated an increased SEP usage following the intervention. If the PSSSTs were followed for their first or second year, would they continue to incorporate the SEPs? Would the frequency of use increase as they became more confident in their teaching? All of these questions would help fill in gaps in the literature.

APPENDIX A – CODING RULES

☐ 3) Planning and Carrying Out Investigations
*Do they have agency over the direction of the investigation?

A		Formulate a question that can be investigated within a scope of the classroom, school laboratory, or field with available resources and, when appropriate, frame hypothesis (that is, a possible explanation that predicts a particular and stable outcome) based on a model or theory. *Do students formulate questions? *Do students make claims? *The common use of hypothesis is simply guessing. *Claims are not guesses, but rather predictions that are based on theory and evidence. *Evidence is data coupled with warrants that serve to link or explain how data supports claims
B		Decide what data are to be gathered, what tools are needed to do the gathering, and how measurements will be recorded. * Do students have agency over the protocol or experimental design?
C		Decide how much data are needed to produce reliable measurement and consider any limitations on the precision of the data. *Do students argue about the merits of the design? *Do they think about the potential error that may have resulted from their data collection?
D		Plan experimental or field-research procedures, identifying relevant independent and dependent variables and, when appropriate, the need for controls. *Do students attempt to minimize extraneous factors?
E		Consider possible confounding variables or effects and ensure that the investigator's design has controlled for them. *Do students skeptically critique the protocol and experimental design?

☐ 4) Analyzing and Interpreting Data

A		Analyze data systematically, either to look for salient patterns or to test whether data are consistent with an initial hypothesis. * Do students analyze the data? *Are they searching for patterns? *Do they relate it back to initial claims?
B		Recognize when data are in conflict with expectations and consider what revisions in the initial model are needed. *Are students able to engage in iterative process to improve the design and/or results of the study (enacted or imagined)?
C		Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information and computer technology to collate, summarize, and display data and to explore relationships between variables, especially those representing input and output. *Do students transform the raw data in a meaningful fashion? *Do the students find slopes of a line in order to find a relationship?
D		Evaluate the strength of a conclusion that can be inferred from any data set, using appropriate grade-level mathematical and statistical techniques. *Do the students find the average in lower grades and % error in upper grades? *If students find the slope of a line, do they use R-squared (correlation coefficient) to view the statistical confidence?
E		Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlation relationships. *Are new questions or claims formulated? *Are the patterns related to theory?
F		Collect data from physical models and analyze the performance of a design under a range of conditions. *Determining how a physical model operates when variables are changed.

☐ 6) Constructing Explanations and Designing Solutions

A		Construct their own explanations of phenomena using their knowledge of accepted scientific theory and linking it to models and evidence. *Students use evidence to gain confidence in their claims to the point where the backing of the claim becomes accepted by the community.
B		Using primary or secondary scientific evidence and models to support or refute an explanatory account of a phenomenon. *Rebut claims using data. *Transformed data can serve as data (calculated velocity from distances, temperature as a measure of energy, spectrophotometer readings as indicator of concentration of absorbing materials in a solution, etc.) *Inferential evidence can be used as data (similar to distributive property - if a=b and b=c, then a=c)
C		Offer causal explanations appropriate to their level of scientific knowledge. *Students use disciplinary knowledge to form explanations. *Disciplinary knowledge is the canonical schemes that are indicative to the domain (ex. citing gravitation as responsible for objects falling at ever increasing rates, kinetic molecular theory, Hooke's law, more dense air tend to displace less dense air, etc.)
D		Identify gaps or weaknesses in explanatory accounts (their own or those of others). *Critiquing the work for errors and places where improvements can be made.
E		Solve design problems by appropriately applying their scientific knowledge.
F		Undertake design projects, engaging in all steps of the design cycle and producing a plan that meets specific design criteria.
G		Construct a device or implement a design solution.
H		Evaluate and critique competing design solutions based on jointly developed and agreed-on design criteria

APPENDIX B – INTERVIEW QUESTIONS

Research Question: *How did the intervention and educative supports influence* PSSSTs *in incorporating SEPs into planning for classroom lessons?*

Question #	Main	Follow-up	Probe
Rapport Builder	**How is everything going at your placement?**	**Are the students responding to you in a positive manner?**	**Do you think this the right profession for you?**
1	**What aspects of science are important for students to learn?**	**How does content compare to SEPs in terms of importance?**	**Can you give an example using a particular topic in your classroom?**
2	**Are SEPs able to be incorporated into daily lessons?**	**What might impede incorporation of SEPs into daily lessons?**	**Have you attempted incorporation of SEPs into lessons other than those assigned for this course?**
3	**Are typical laboratory exercises able to be adapted to include SEPs?**	**What modifications can be made so that typical laboratory exercises can incorporate SEPs?**	**Was there anything that you found to be helpful for modifying laboratory exercise to incorporate SEPs?**
4	**Was there anything from the interventions that made incorporation of SEPs into the classroom easier?**	**Why was that helpful?**	**Is there something else that could be done during the intervention that would help PSSSTs incorporate SEPs into classroom practice?**
5	**What educative supports (handouts, tables, and tools) helped to incorporate SEPs into the planning process?**	**What specifically was useful?**	**What other educative supports would help you incorporate SEPs into the classroom lessons?**

APPENDIX C – PSSSTS' LESSON PLAN INFORMATION

LP2

PSSST	Grade Level	Course	Lesson Name	Scientific Concepts	Sub-SEPs Included
Kristine	10	Chemistry	Chemical and Physical Changes	Recording change in mass, burning and melting, reading instruments	6A, 6B, 6C
Kurt	7 & 8	Physical Science	Speed vs. Time	Graphing Motion	4A
Lisa	9	Biology	Organisms on Earth Interact Differently	Living and Non-Living Things	6A, 6C
Alexis	10	Chemistry	Energy In Many Forms	Energy, Heat, Phase Change	4C, 6A, 6B, 6C
Jennifer	7 & 8	Physics	Accelerating Motion	Acceleration	4A
Robert	Not Noted	Not Noted	Matter is made of Particles	States of Matter	6A, 6B, 6C

LP 3

PSSST	Grade Level	Course	Lesson Name	Scientific Concepts	Sub-SEPs Included
Kristine	10	Chemistry	Atomic Theory	Atoms and Molecules	6A, 6C
Kurt	7 & 8	Physical Science	Interpreting Position vs. Time	Graphical Models	4A, 4C, 6A
Lisa	9	Biology	Energy, Producers, Consumers	Structure and Function of Living and Nonliving Things	None
Alexis	10	Chemistry	Density	Significant Figures, Mass, Volume	4C, 6C
Jennifer	7 & 8	Physics	Tools to Tell if it is Moving?	Graphing, Speed, Slope, Acceleration	None
Robert	Not Noted	Not Noted	Atomic Structure	Periodic Trends	4A, 4B, 6A, 6C

WP 4

PSSST	Grade Level	Course	Lesson Name	Scientific Concepts	Sub-SEPs Included
Kristine	10	Chemistry	Temperature, Heat, Energy	Phases of Matter, Particles in Motion	4A, 6A, 6B, 6C
Kurt	7 & 8	Physical Science	Newton's Laws	Forces, Masses, Acceleration, Ramps	6A, 6B, 6C
Lisa	9	Biology	Energy for Life Processes	Biochemical Equations, Respiration, Krebs Cycle	6A
Alexis	10	Chemistry	Chemical Equilibrium	Chemical Reactions, Compounds, Bonding	None
Jennifer	7 & 8	Physics	Is it in Motion	Speed, Velocity, Acceleration, Graphing, Slope	4C
Robert	Not Noted	Not Noted	Atoms are Building Blocks of Matter	Mass, Binding Energy, Percent Yield, Chemical Separation	3D, 3E, 4D, 6C

WP 5

PSSST	Grade Level	Course	Lesson Name	Scientific Concepts	Sub-SEPs Included
Kristine	10	Chemistry	Atomic Theory – Bonding	Ionic and Covalent Bonding	4E, 6B, 6D
Kurt	7 & 8	Physical Science	Simple Machines	Levers, Forces, Distances	6G
Lisa	9	Biology	Energy and Life	Biochemical Reactions, Energy in Food, Cell Growth	3E, 4B, 6A, 6B, 6C, 6E
Alexis	10	Chemistry	Acid & Bases, Mole Ratio	Synthesis Reactions, Buffers, Writing Laboratory Reports	None
Jennifer	7 & 8	Physics	Inertia	Forces, Acceleration, Friction, Newton's Laws	3A, 4A, 6A, 6C
Robert	Not Noted	Not Noted	Atomic Theory	Metals, Spectroscopy, Electron Configuration	6A, 6B, 6C

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